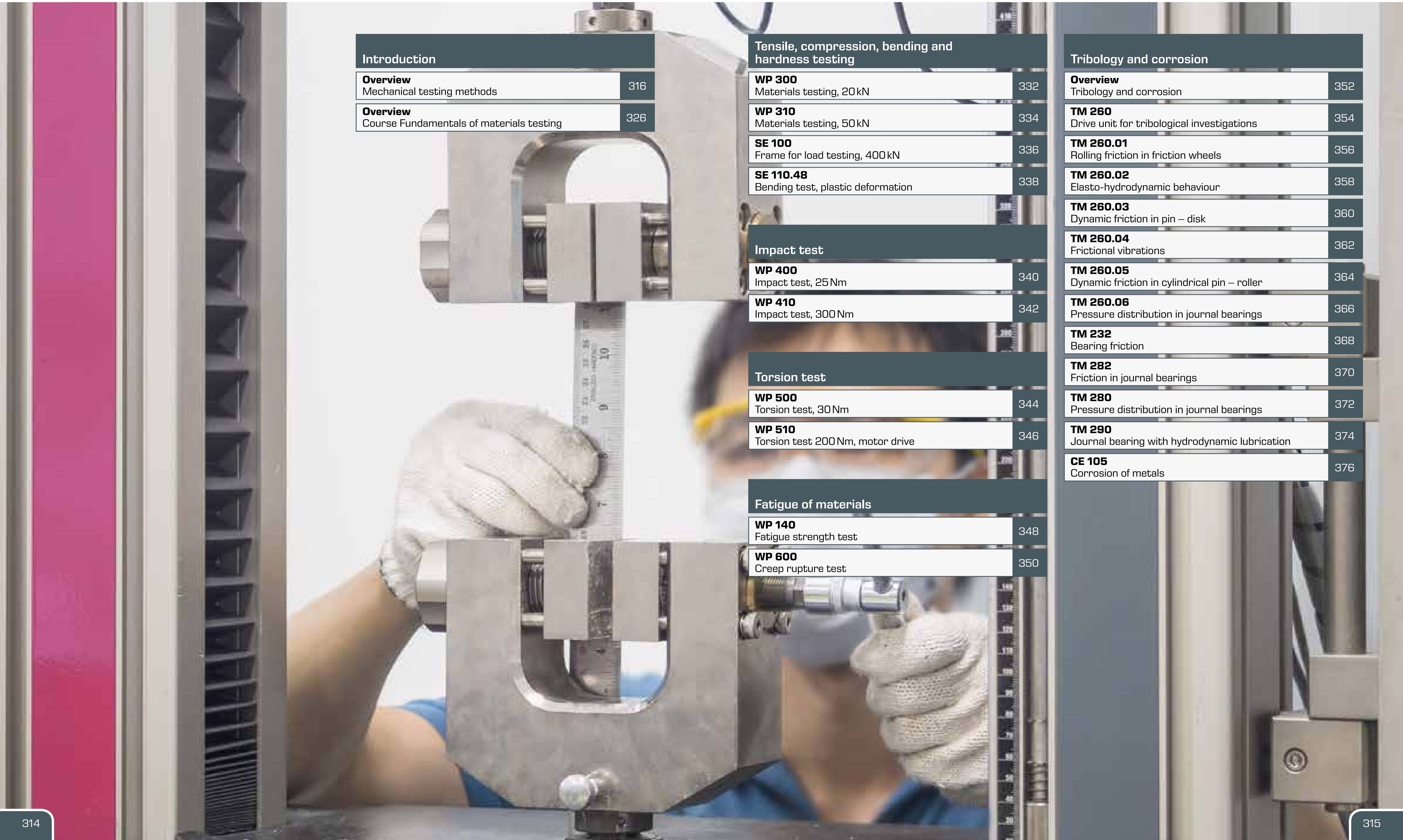
6

Materials testing



Introduction

Tensile, compression, bending and hardness testing

Impact test

Torsion test

Fatigue of materials

Tribology and corrosion

Mechanical testing methods

Materials testing studies the behaviour of materials under different loads. In particular, the relationship between the acting forces and the resulting deformation and the limit stresses that lead to failure of components are considered.

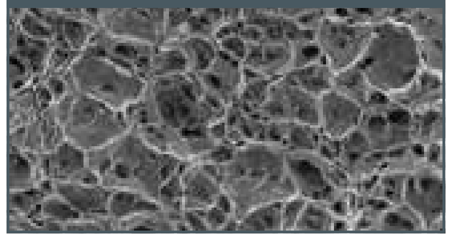
The characteristic values obtained from the testing process are used for materials development, designing components and in quality assurance. There is a range of standardised testing methods to characterise the mechanical properties of materials as precisely as possible:

Mechanical property	Testing method
Elasticity, plasticity	Tensile test, compression test, bending test, torsion test
Material behaviour under static load	
Creep behaviour	Creep rupture test
Hardness	Brinell, Rockwell, Vickers
Toughness	Impact test
Fatigue behaviour, fatigue strength	Wöhler fatigue test

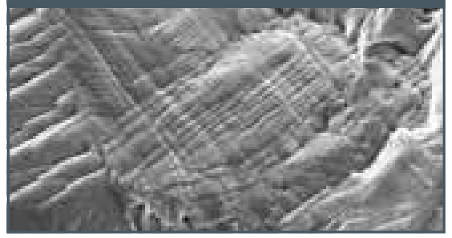
The fracture behaviour is used to characterise the material.
The summary below shows a relationship between failure mechanism and stress:

Fracture type	Fracture mechanism	Stress
Forced fracture ■ occurs abruptly ■ matte or glossy crystalline and partially fissured surface over the entire cross section; in ductile fractures, shear lips often occur at the edge	**Static overstress** **a)** low-deformation cleavage fracture occurs when the largest direct stress exceeds the cleavage fracture stress **b)** ductile fracture (microscopic honeycomb fracture) occurs when the largest shear stress exceeds the yield stress **c)** a low-deformation intergranular fracture can occur with a reduction of the grain boundary cohesion under the influence of direct stress	Tensile test, impact test
Fatigue fracture ■ can develop following repeated stress under the influence of shear or direct stress ■ low-deformation fracture	**Dynamic overstress** Starting from notches or imperfections, oscillatory cracks propagate through the material. When the material strength is exceeded, the remaining surface fractures by way of a forced fracture.	Wöhler fatigue test
Creep fracture ■ continuous time-dependent process ■ sets in at higher temperatures and eventually leads to fracture, although the material is loaded below the hot yield point ■ pores on grain boundaries lead to material damage	**Static stress, e.g. increased temperature** Countless cracks form independently of each other	Creep rupture test

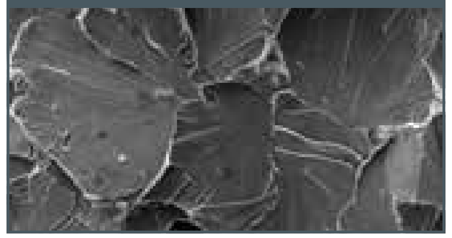
Honeycomb fracture



Fatigue fracture

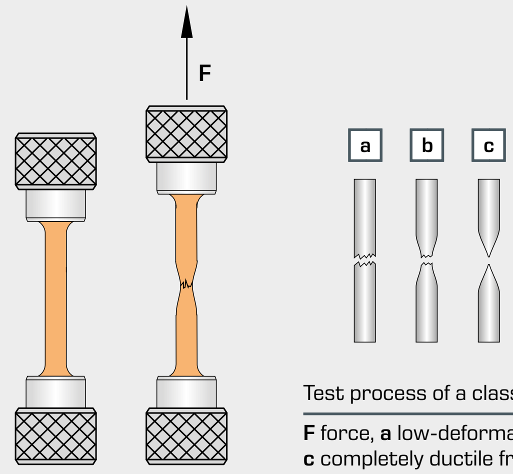


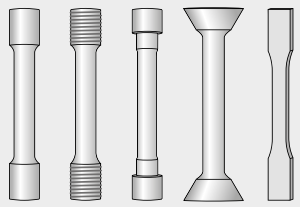
Cleavage fracture



Tensile test to determine the tensile strength and elongation at fracture

The tensile test is the most important testing method in destructive materials testing. A standardised specimen with a known cross section is loaded uniformly with relatively low increasing force in the longitudinal direction. A uniaxial stress state prevails in the specimen until contraction commences. The ratio of stress to strain can be shown from the plotted load-extension diagram.

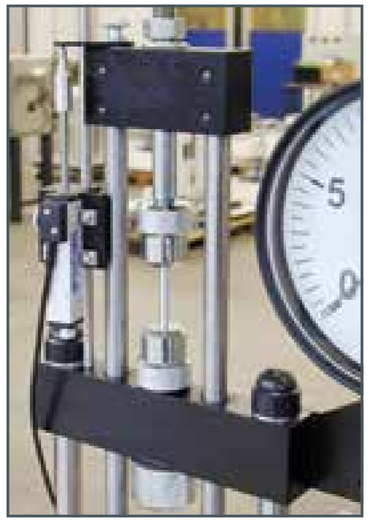




Selection of specimen forms for tensile tests according to DIN 50125

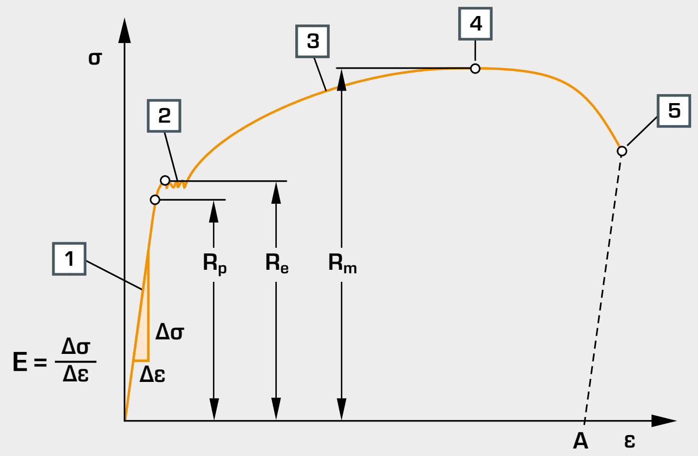
Test process of a classic tensile test

F force, **a** low-deformation fracture, **b** ductile fracture, **c** completely ductile fracture

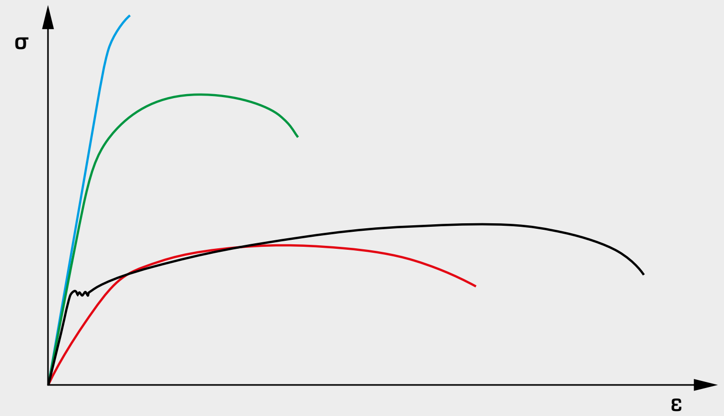


Stress-strain diagram

The stress-strain diagram shows clearly the different behaviour of the individual materials and provides the characteristic values for tensile strength R_m, yield strength R_e, proportional limit R_p, elongation at fracture **A** and the elastic modulus **E**.



σ stress, ε strain, R_p proportional limit, R_e yield strength, R_m tensile strength, **A** elongation at fracture
1 Hooke's straight line, **2** Lüders strain, **3** strain hardening region, **4** start of contraction, **5** fracture

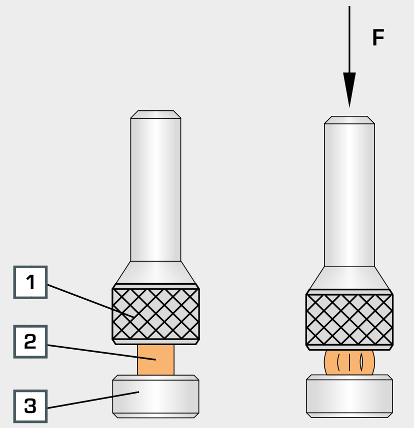


Every material has a characteristic profile of stress and strain.

■ hardened steel: very high tensile strength
■ tempered steel: high tensile strength
■ low-strength steel: very high elongation, low tensile strength
■ aluminium alloy: low elastic modulus

Mechanical testing methods

Compression test to determine flow curves

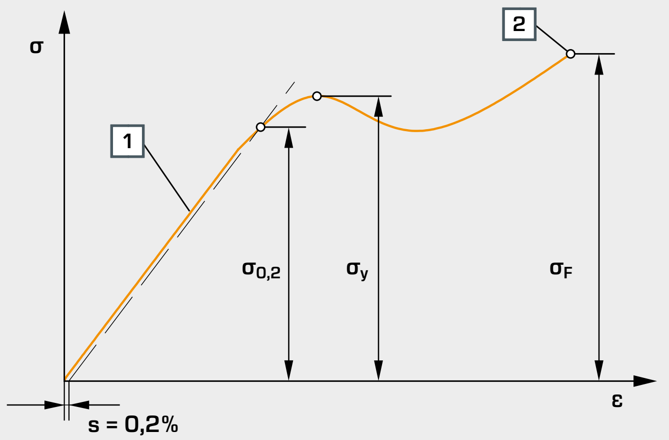


Test process in the compression test

1 thrust plate, **2** specimen, **3** pressure plate, **F** test load

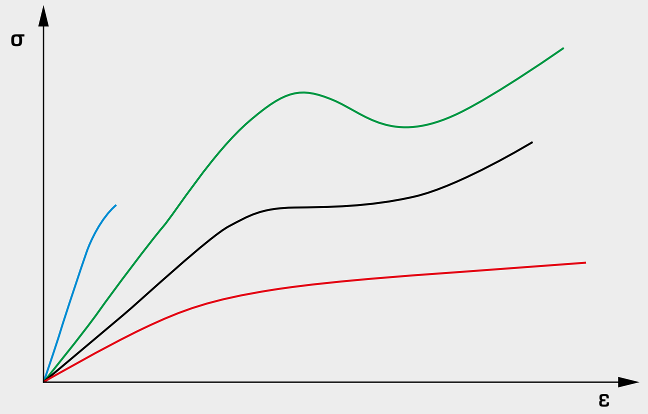
Compression tests are less significant for testing metallic materials compared to tensile tests. However, when studying building materials such as natural stone, brick, concrete, wood etc., the compression test is fundamentally important. A standardised specimen with a known cross section is loaded uniformly with low increasing force in the longitudinal direction. A uniaxial stress state prevails in the specimen. The ratio of stress to compression can be shown from the plotted force-path diagram. The **stress-compression diagram** shows clearly the different behaviour of the various separate materials and provides the characteristic values for compression strength, 0,2% offset yield point and the compression yield stress.

Stress-compression diagram



Stress-compression diagram

σ stress, **ε** compression, **s** 0,2% offset yield point, σ_y compression yield stress, σ_F compression strength, **1** elastic region, **2** fracture



Every material has a characteristic profile of compression and stress.

- brittle plastic, no compression strength
- ductile plastic with compression yield stress
- ductile plastic without compression yield stress
- ductile plastic without fracture

Various methods for determining hardness

Hardness refers to the mechanical resistance with which a body opposes the intrusion of another body.

Principle of the Brinell hardness test

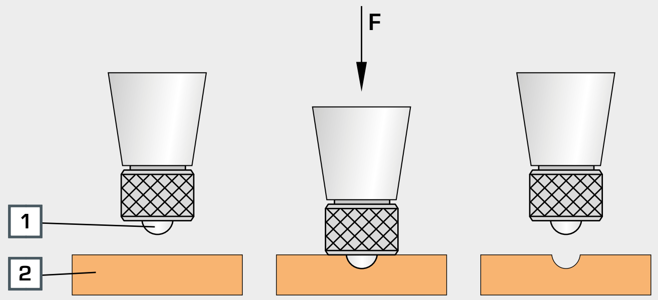
In this test method, a standardised test body – a hard metal sphere – is pressed into the workpiece under defined conditions. The surface of the lasting impression is then measured optically. The impression surface is calculated from the impression diameter and the sphere diameter. A triaxial stress state develops in the specimen, underneath the impressing test body.

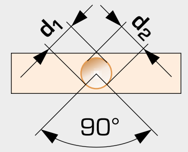
The Brinell hardness is calculated from the test load and impression surface of the spherical segment.

$$HB = \frac{0{,}102 \cdot F}{A_B} \qquad 0{,}102 = \frac{1}{9{,}81} = \frac{1}{g}$$

to convert N into kgf

HB Brinell hardness value, **F** test load in N, A_B impression surface in mm^2, **g** = 9,81 gravitational acceleration



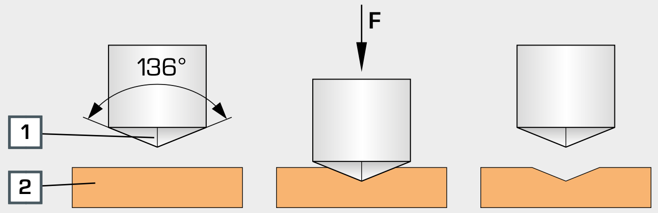


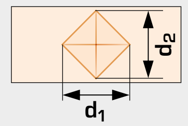
Test process and optical measurement of the permanent indentation

1 hard metallic sphere, **2** specimen, **F** test load, d_1 and d_2 diameters perpendicular to each other

Principle of the Vickers hardness test

The test method is similar to the Brinell hardness test. Unlike the Brinell method, a pyramid-shaped diamond is used as the test body. The impression diagonal is determined by measuring the two diagonals d_1 and d_2 and by taking the average. The Vickers hardness is the quotient of the test load and impression surface.



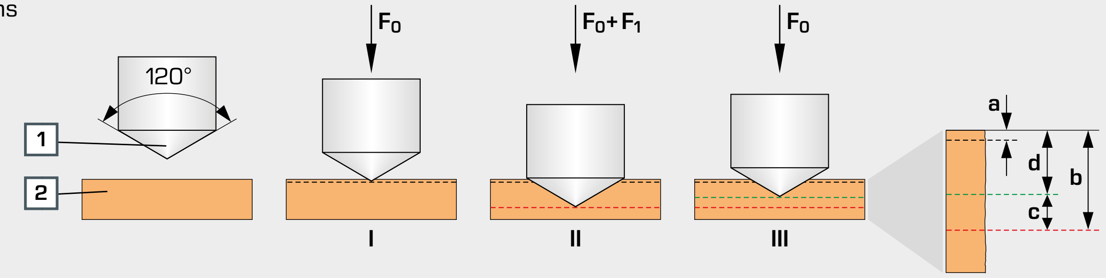


Test process and optical measurement of the permanent indentation

1 pyramid-shaped diamond, **2** specimen, **F** test load, d_1 and d_2 diagonals

Principle of the Rockwell hardness test

Rockwell's hardness test method allows the hardness to be read directly on a dial gauge as the difference of the depths of penetration.



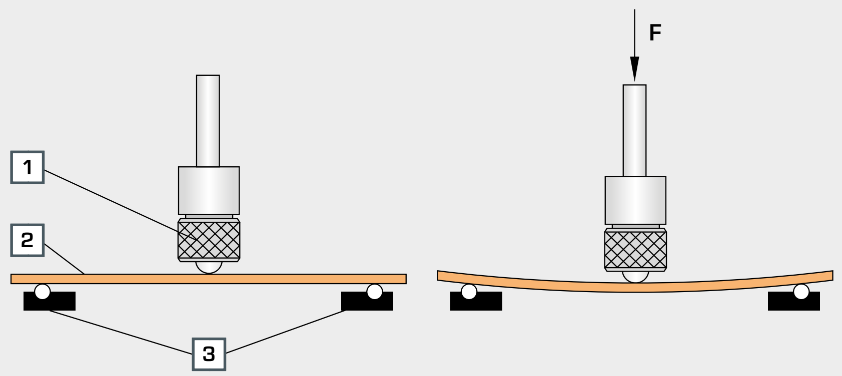
Test process and measurement of the depth of penetration

1 diamond cone, **2** specimen, **I** test pre-load F_0 is applied to the test body and the dial gauge is set to zero, **II** additional test load F_1 is applied for a given duration, **III** additional test load F_1 is removed, **a** depth of penetration due to test pre-load F_0, **b** depth of penetration due to additional test load F_1, **c** elastic recovery after removal of the additional test load F_1, **d** lasting depth of penetration h

Mechanical testing methods

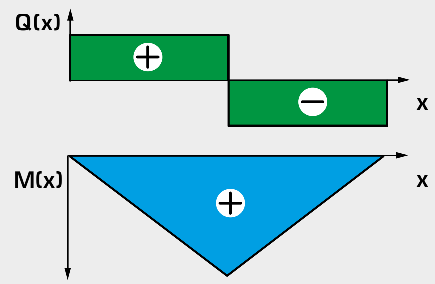
Bending tests for the study of deformation behaviour

The most frequently studied bending load in materials testing is the three-point bending test. Using this method, a beam mounted on two supports is studied under a single force applied to the centre. The bending test demonstrates the relationship between the load of a bending beam and its elastic deformation. The effects of modulus of elasticity and second moment of area are shown.



Test process in the three-point bend test

1 pressure piece, **2** specimen, **3** two supports on which the beam is mounted, **F** test load



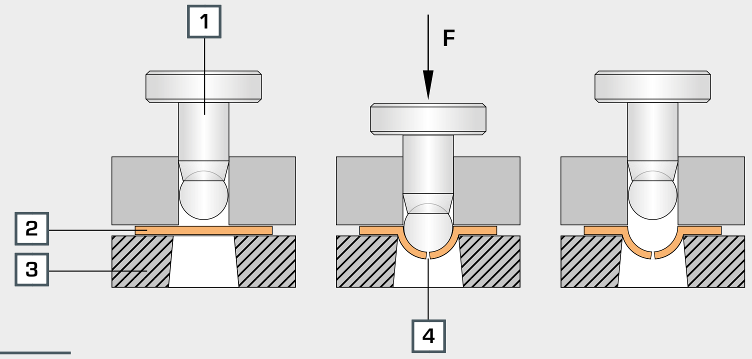
Bending stress with profile of shear forces and bending moment

Q shear force, **M** bending moment, **x** distance

Cupping test to determine the cupping capacity (cold formability) of sheets and strips

Sheets and strips are subject to high demands in terms of their cold formability for deep drawing. No cracks are allowed to occur when working with these thin sheets. The cupping test checks the cold formability in sheets.

The cupping specimen to be tested is clamped between a blank holder and die and is indented with a hardened spherical stamp (cupped) until the specimen cracks. The depth achieved is considered a standard of comparison for the cold formability. In addition, the type of crack and the surface structure of the sagging area are analysed.



Test process in the cupping test

1 stamp, **2** specimen, **3** die, **4** crack, **F** test load

Shear test to study the load capacity against shearing

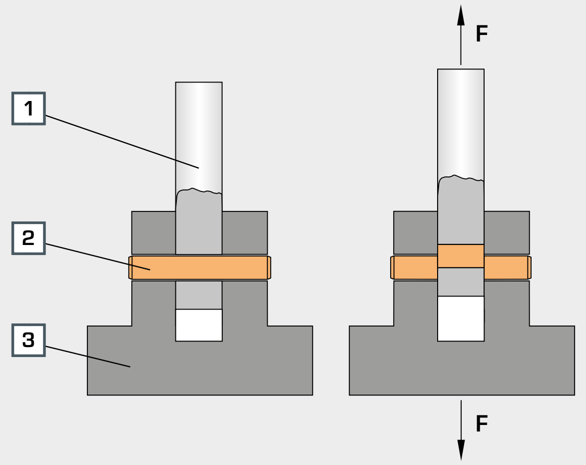
The shear test is applied when testing screws, rivets, pins and parallel keys in order to determine the shear strength of the material or the behaviour of the material under shear strain. To do this, the shear stresses are produced in the specimen by means of external shear forces until the specimen shears off. The resistance of a material against the shear stress can be determined by two different methods, the single-shear and the double-shear testing method.

In the double-shear method, the specimen is sheared off at two cross sections. In the single-shear process, the specimen only shears away at one cross section. Calculating the shear strength in the two processes differs in the cross-sectional area to be applied. The shear strength determined in the shear test is important in the design of bolts, rivets and pins, as well as for calculating the force required for shears and presses.

$$\tau = \frac{F}{2 \cdot A}$$

Shear strength in the double-shear method

τ shear strength, **F** force, **A** shearing surface



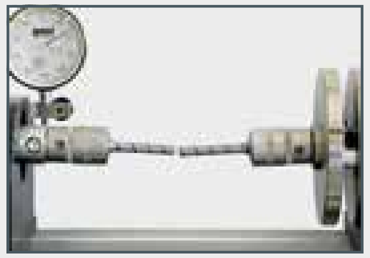
Test process in the double-shear test

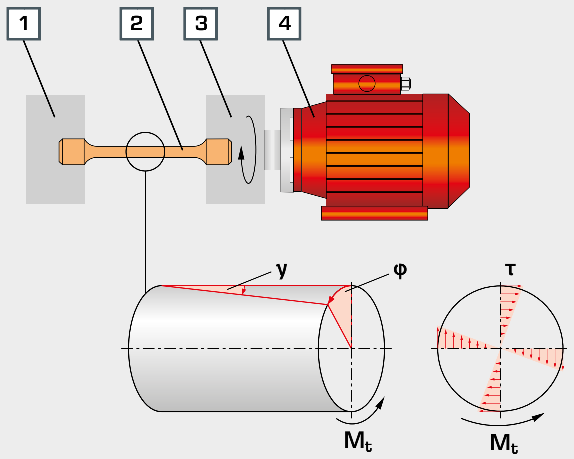
1 pull strap, **2** specimen, **3** housing, **F** test load

Torsion test to study the plastic behaviour of materials

Components that are subjected to rotary movements are twisted. This twisting is referred to as torsion. The torsional stiffness determined in the torsion test serves as orientation for the load capacity of the material. This method is applied in shafts, axles, wires and springs and to assess the impact behaviour of tool steels.

In the torsion test, a specimen is clamped at one end and subjected to the load of a steadily increasing moment, known as the twisting moment or torsional moment. The twisting moment causes shear stresses in the cross-section of the specimen and a stress state that leads to deformation and ultimately to fracture.





Test process in the torsion test

1 rigid clamping, **2** specimen, **3** rotating clamping, **4** drive; M_t twisting moment, **γ** shearing angle, **φ** twisting angle, **τ** shear stress

Mechanical testing methods

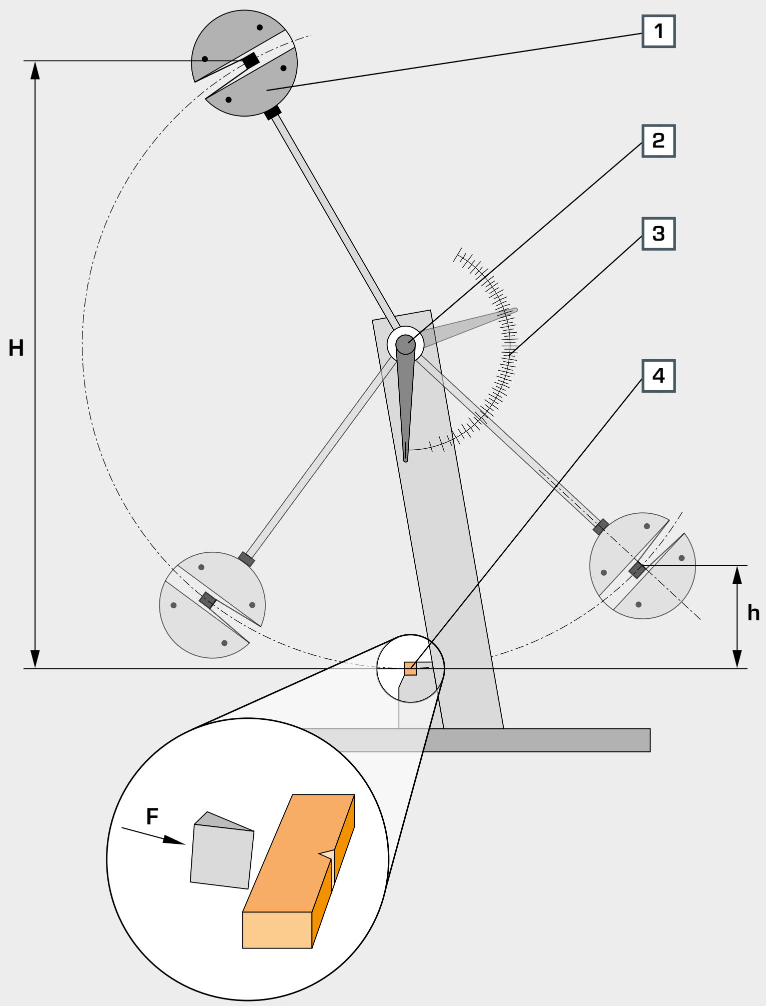
Impact test to determine the toughness property

The impact test is a method with sudden loading and is suitable primarily for determining the cleavage fracture tendency or toughness property of a material. This test method does not provide any values of material characteristics. The determined values of the impact test, the notched-bar impact strength, do not fit directly into calculations on strength. Rather, they help only with a rough selection of materials for a specific task.

The deformation behaviour is often an important criterion for the selection of materials. It can be used to identify quickly which of the selected materials are brittle or tough. The brittleness of the material does not depend on the material alone, but also on other external conditions such as temperature or stress state.

Different testing methods are used to determine the notched-bar impact strength. In the Charpy test, the test body is mounted on two sides and a pendulum strikes the centre of the test body at the height of the notch. In the Izod and Dynstat tests, the test body is upright and a pendulum strikes the free end of the test body above the notch.

Principle of the Charpy notched-bar impact test

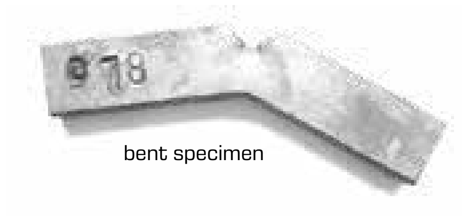


1 pendulum hammer, **2** axis of rotation, **3** scale with trailing pointer, **4** notched specimen; **H** height of fall, **h** height of rise, **F** force

In the notched-bar impact test, a pendulum hammer falls down from a maximum height. At its lowest point, the hammer strikes the rear of a notched specimen according to Charpy's principle. If the abutment penetrates or passes through the specimen, the hammer dissipates its impact energy to the specimen. The residual energy of the hammer is reduced when swinging through the lowest possible point (zero point) and the hammer decelerates. When the hammer swings through the zero point, the trailing pointer is dragged along and the applied work for the notched-bar impact is displayed on a scale.

The shape of the notched-bar specimen is standardised.

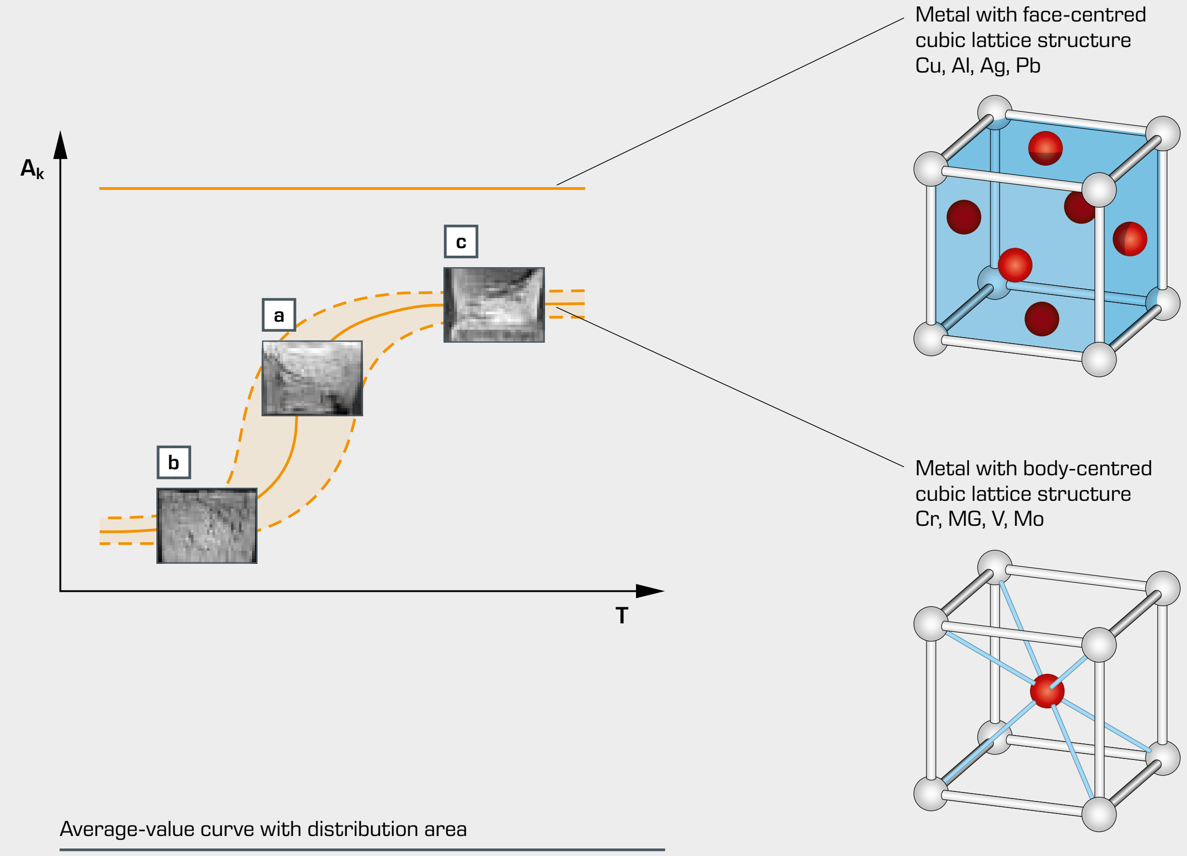
The necessary notched-bar impact work is the force needed to penetrate a defined notched specimen. The notched-bar impact strength determined from the notched-bar impact work is a measure of the brittleness of the material.



bent specimen

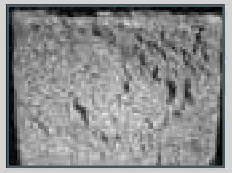
destroyed specimen

Notched-bar impact work-temperature diagram



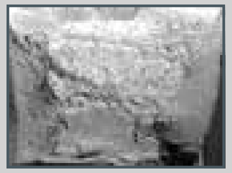
Average-value curve with distribution area

A_k notched-bar impact work, **T** temperature,
a transition region (steep front) with mixed fractures,
b depth position with low-deformation fractures,
c height position with ductile fractures



Low-deformation fracture
(brittle materials)

- material separation by direct stress over cleavage planes
- trans-crystalline fracture
- glossy, practically deformation-free fracture surface



Mixed fracture

- external ductile fracture (microscopic honeycomb fracture), internal low-deformation fracture (microscopic cleavage fracture)

Ductile fracture
(tough materials)

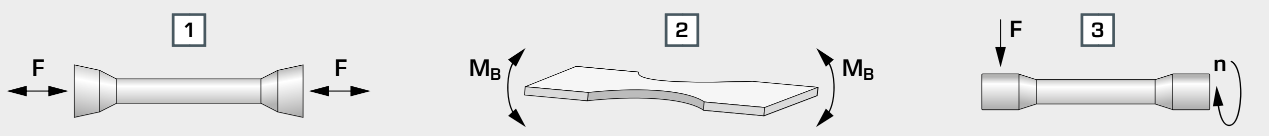
- ductile deformation, fracture due to grains
- matte, heavily deformed fracture surface

Mechanical testing methods

Material fatigue

Fatigue strength test

The fatigue strength defines the load limit up to which a material that is loaded dynamically withstands without breaking. Moving machine parts in particular are subject to dynamic loads, caused by vibrations for example. In this case, a fracture occurs after a high number of load cycles with stresses that are far below the yield point and far below the fracture stress.

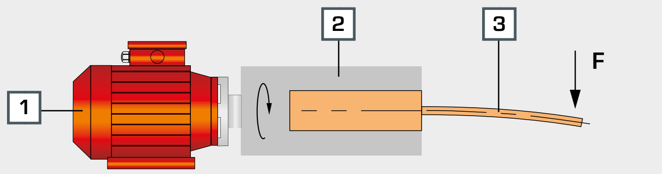


Differently loaded specimens

1 specimen with tensile and compression stress, **2** specimen with stress from alternating bending, **3** specimen with stress from rotary bending; **F** force, $\mathbf{M_B}$ bending moment, **n** speed

Principle of the fatigue strength test with stress on rotary bending

In the fatigue strength test, a rotating, cantilever-mounted specimen is subjected to a bending moment. In the cylindrical specimen, this creates an alternating stress due to rotary bending. After a certain number of load cycles, the specimen fractures because of material fatigue.



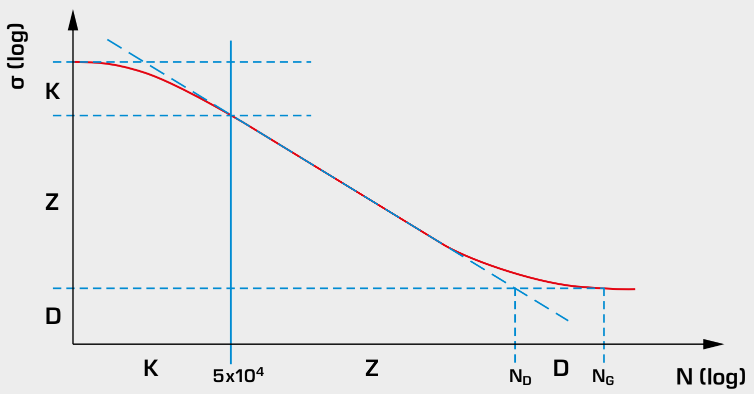
1 drive, **2** rigid clamp, **3** rotating specimen

Analysis of the fracture surface following the fatigue strength test

1 to **3** fatigue fracture, **4** final force fracture

Wöhler diagram for analysis of the experiment

The relationship between load change until fracture and the associated stress load is plotted in a Wöhler diagram.



N load cycles, **σ** stress load, **K** short-term strength, **Z** fatigue strength, **D** endurance strength, $\mathbf{N_D}$ number of load cycles from endurance strength is given, $\mathbf{N_G}$ limit load cycles

The Wöhler diagram contains three regions:

Short-term strength: exceeds a load limit at which the specimen will be damaged in principle

Fatigue strength: with increasing load, there is a decreasing number of load cycles until fracture of the specimen

Endurance strength: maximum stress that a specimen can endure indefinitely and without perceptible deformation, at least up to the number of load cycles $\mathbf{N_G}$

Service life: Number **N** of load cycles until fracture at a certain load

Creep rupture test to study creep

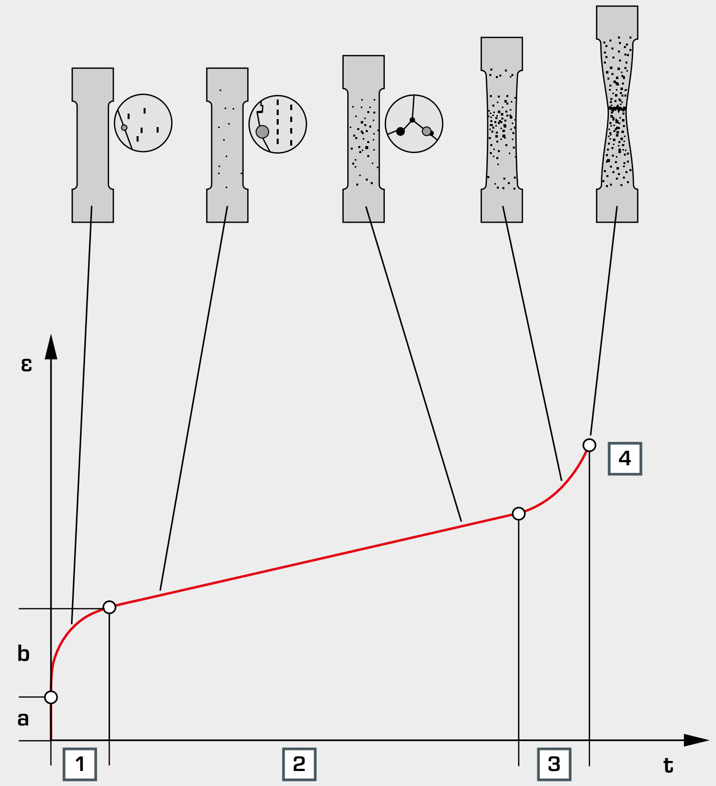
Materials behave differently under lasting static loads at increased temperatures than they do under the same load at room temperature. After a certain amount of time, increased temperatures under stresses below the hot yield point and without an increase in load lead to a slow but steady irreversible plastic deformation, also known as creep. After a sufficiently long, even load time, this leads to fracture of the specimen.

Principle of the creep rupture test

In the creep rupture test, a specimen is subjected to load at constant stress and constant temperature. This experiment is performed multiple times with different stresses, but always at the same temperature. The plastic deformations are measured in continuous intervals. All measured values can then be transferred to a creep diagram. The measured elongation shows a characteristic curve, which is known as the creep curve. The creep rupture test determines the characteristic values for the creep strength and the various strain values.

Creep curve

If the elongation is plotted over time, we get the creep curve.



Change in the specimen over time

t time, **ε** elongation, **1** primary creep, **2** secondary creep, **3** tertiary creep, **4** specimen fracture, **a** elastic deformation, **b** plastic deformation

Creep strength (creep fracture limit / creep strain limit): mechanical stress, which causes permanent elongation or fracture

Strain values: creep, permanent elongation, plastic initial strain, inelastic recovery

In the creep curve we differentiate between three phases in technical creep regions:

Phase 1, the primary creep with decrease of the initially very high creep rate. Here, the influence of the material strength prevails (rapid creep).

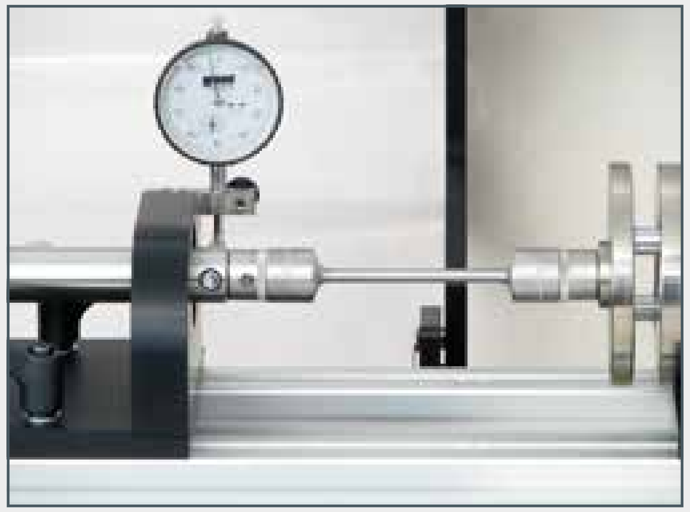
Phase 2, the secondary creep with virtually constant creep rate. The dislocation climb when overcoming flow obstacles is located in a steady-state equilibrium.

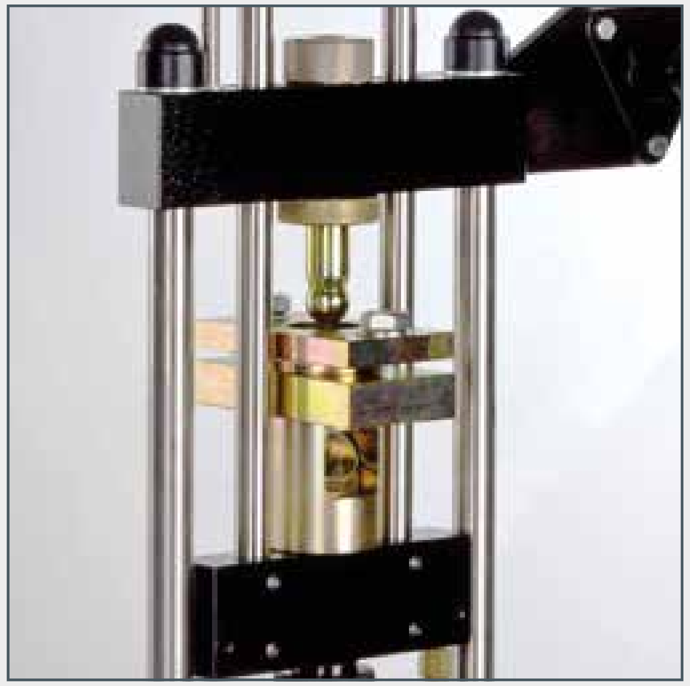
Phase 3, the tertiary creep with again increasing creep rate until fracture due to increasing necking and increase in the effective stresses. Phase 3 can be very short in the case of low-deformation fractures.

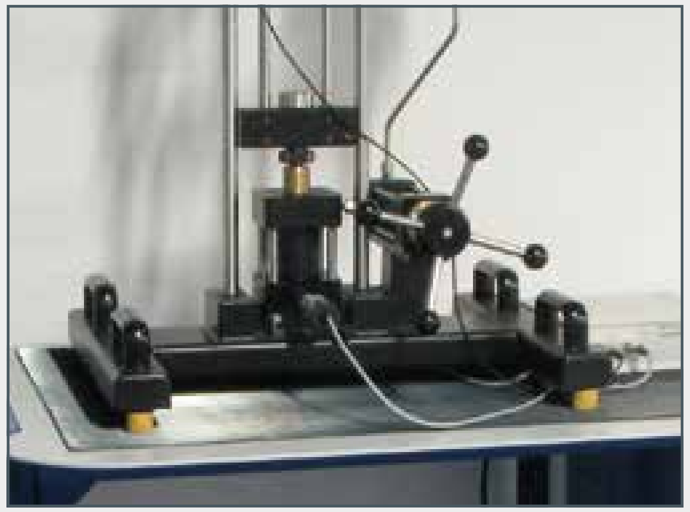
Course
Fundamentals of materials testing

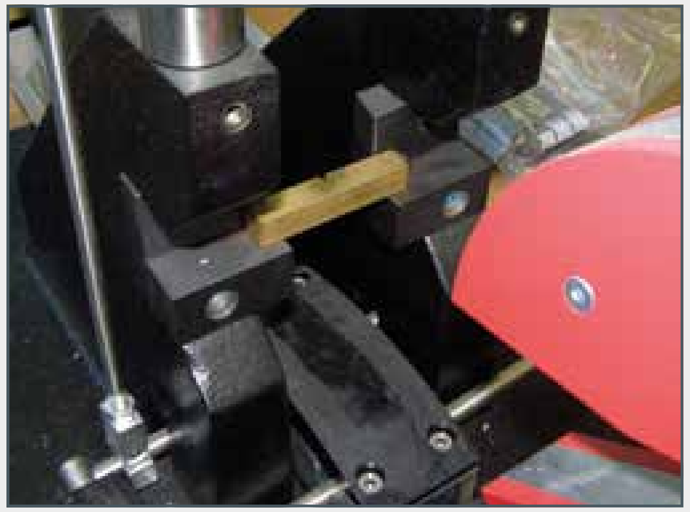
Series WP

A complete course in the fundamentals of materials testing









Course
Fundamentals of materials testing

Using experimental units, students learn how to analyse materials by learning about different test methods for determining material properties and for assessing and classifying “unknown” materials.

The complete course includes topics such as:

- elastic and plastic deformation
- tensile strength, stress, strain, force-extension diagram, stress-strain diagram
- elongation at fracture, necking, fracture behaviour
- Brinell hardness test
- compression test, compression strength, compression yield stress, stress-compression diagram
- bending test
- cupping test, cold formability
- shear test, shear strength
- torsion test, torsion, shear stress, torsional stiffness, impact behaviour
- Charpy notched-bar impact test, toughness property, notched-bar-impact work-temperature diagram
- fatigue strength test, Wöhler diagram, analysis of the fracture surface
- creep rupture test, creep, strain-time diagram (creep curve)

The compact WP 300 experimental unit generates a 20 kN test load

- classic experiments from destructive materials testing
- observation of the experiment in all details and phases
- clear demonstration of relationships between rising forces and change in various materials
- mobile use thanks to compact and lightweight design
- preparation display and storage of data with the WP 300.20 system for data acquisition

The WP 310 experimental unit generates a 50 kN test load

- classic experiments from destructive materials testing with measuring results based on industrial standards
- trainer for experiments based on industrial standards
- acoustic overload signal for test loads
- the scope of delivery includes GUNT software for analysing the experimental data

The compact WP 400 experimental unit generates a 25 Nm work capacity

- Charpy notched-bar impact test for quality control and analysis of the fracture behaviour in metallic materials
- pendulum impact tester based on DIN EN ISO 148-1
- various safety devices for conducting experiments safely and optional protective cover for the WP 400.50 operating area
- preparation display and storage with the WP 400.20 system for data acquisition

The WP 410 experimental unit generates a 300 Nm work capacity

- Charpy notched-bar impact test with increased work capacity
- pendulum impact tester based on industrial standards / DIN EN ISO 148-1
- safe experiments thanks to two-hand release of the hammer and optional protective cage for pendulum impact tester WP 410.50
- preparation display and storage with the WP 410.20 system for data acquisition

The compact WP 500 experimental unit generates reference moments of 30 Nm

- generates the twisting moment by means of a worm gear
- measure the twisting moment with strain-gauge measuring shaft and encoder for measuring the twisting angle
- the scope of delivery includes GUNT software for analysing the measured values

The WP 510 experimental unit generates reference moments of 200 Nm

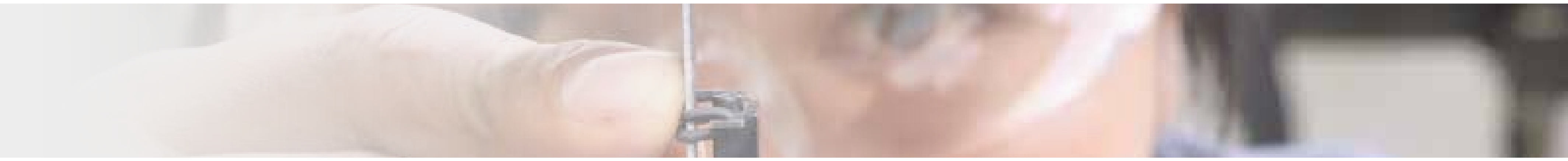
- torsion test based on industrial standards; experiments conducted with the aid of a motor
- different torsional velocities, clockwise and anticlockwise
- microprocessor-based measuring technology
- the scope of delivery includes GUNT software for analysing the experimental data

The compact WP 140 experimental unit is used to conduct fatigue strength tests

- fatigue strength of bars under reverse bending stress
- digital counter displays load cycles
- automatically shuts down when the test bar fractures
- preparation display and storage with the WP 140.20 system for data acquisition

The compact WP 600 experimental unit is used to conduct creep rupture tests

- simple creep rupture tests with lead and plastic specimens
- experiments can be conducted at room temperature
- cooling elements allow experiments to be conducted below room temperature
- experiments last from a few minutes to an hour



Course
Fundamentals of materials testing

Accessories for various materials tests

WP 300, 20 kN test load

Tensile tests

WP 300.02	Set of 4 tensile specimens, Al, Cu, St, CuZn
WP 300.21	Set of 4 tensile specimens, Al
WP 300.22	Set of 4 tensile specimens, Cu
WP 300.23	Set of 4 tensile specimens, St
WP 300.24	Set of 4 tensile specimens, CuZn
WP 300.14	Clamping device for flat tensile specimens
WP 300.25	Set of 4 tensile specimens, flat, Al, Cu, St, CuZn

Compression tests

WP 300.05	Compression plates for compression tests, large
WP 300.70	Set of 4 compression specimens, gypsum
WP 300.71	Set of 4 compression specimens, wood
WP 300.72	Set of 4 compression specimens, plastic

Brinell hardness tests

WP 300.03	Set of 4 hardness specimens, Al, Cu, St, CuZn
WP 300.31	Set of 4 hardness specimens, Al
WP 300.32	Set of 4 hardness specimens, Cu
WP 300.33	Set of 4 hardness specimens, St
WP 300.34	Set of 4 hardness specimens, CuZn
WP 300.12	Measuring magnifier for Brinell hardness test

Bending tests

WP 300.04	Bending test device

Cupping tests

WP 300.11	Device for cupping tests
WP 300.41	Set of 5 cupping specimens, Al
WP 300.42	Set of 5 cupping specimens, Cu
WP 300.43	Set of 5 cupping specimens, St
WP 300.44	Set of 5 cupping specimens, CuZn

Shear tests

WP 300.10	Device for shear tests, double-shear
WP 300.13	Device for shear test, single-shear
WP 300.52	Set of 5 shear specimens, Cu

Spring tests

WP 300.06	Experimental setup for spring test, helical spring, 2 sets
WP 300.07	Experimental setup for spring test, disk spring

WP 310, 50 kN test load

Tensile tests

WP 310.05	Clamping device for tensile specimens, round and flat
WP 310.12	Set of 10 tensile specimens F10x50 DIN 50125, St (S235JRC+C)
WP 310.06	Clamping device for tensile specimens, threaded end
WP 310.11	Set of 10 tensile specimens B10x50 DIN 50125 M16, St (S235JRC+C)
WP 310.07	Clamping device for tensile specimens, dumbbell-shaped
WP 310.13	Set of 10 tensile specimens, dumbbell-shaped, St (S235JRC+C)

Compression tests

WP 310.04	Compression plates for compression tests
WP 310.15	Set of compression specimens, 4x plastic, 1x wood

Brinell hardness tests

WP 310.01	Experimental setup for Brinell hardness test
WP 300.03	Set of 4 hardness specimens, Al, Cu, St, CuZn
WP 300.31	Set of 4 hardness specimens, Al
WP 300.32	Set of 4 hardness specimens, Cu
WP 300.33	Set of 4 hardness specimens, St
WP 300.34	Set of 4 hardness specimens, CuZn
WP 300.12	Measuring magnifier for Brinell hardness test

Bending tests

WP 310.03	Bending test device
WP 310.81	Set of 25 bending specimens, St

Cupping tests

WP 310.10	Device for cupping tests
WP 300.41	Set of 5 cupping specimens, Al
WP 300.42	Set of 5 cupping specimens, Cu
WP 300.43	Set of 5 cupping specimens, St
WP 300.44	Set of 5 cupping specimens, CuZn

Shear tests

WP 310.02	Device for shear tests, double-shear
WP 300.52	Set of 5 shear specimens, Cu

Spring tests

WP 310.08	Experimental setup for spring test, helical spring
WP 310.09	Experimental setup for spring test, disk spring

WP 400, 25 Nm test load

Impact test

WP 400.01	Set of 10 ISO-V specimens 10x5, construction steel (S235JRC+C)
WP 400.02	Set of 10 ISO-V specimens 10x5, CuZn
WP 400.03	Set of 10 ISO-V specimens 10x10, CuZn
WP 400.04	Set of 10 ISO-U specimens 10x5, free cutting steel (9SMn28)
WP 400.05	Set of 10 GUNT-R7 specimens, free cutting steel (9SMn28)
WP 400.06	Set of 10 GUNT-R5 specimens, free cutting steel (9SMn28)
WP 400.07	Set of 10 GUNT-R7 specimens, heat treatable steel (C45k)
WP 400.08	Set of 10 GUNT-R7 specimens, construction steel (S235JRC+C)
WP 400.09	Set of 10 GUNT-V specimens, construction steel (S235JRC+C)
WP 400.50	Safety cage for pendulum impact tester

WP 500, 30 Nm test load

Torsion test

WP 500.01	Set of 6 torsion specimens, St, Al, CuZn

Material fatigue with WP 140

Fatigue strength test

WP 140.01	Set of 3 specimens, various fillet radii, St

WP 410, 300 Nm test load

Impact test

WP 410.01	Set of 10 ISO-V specimens 10x10, St 37k
WP 410.02	Set of 10 ISO-V specimens 10x10, Cu
WP 410.03	Set of 10 ISO-V specimens 10x10, CuZn
WP 410.50	Safety cage for pendulum impact tester

WP 510, 200 Nm test load

Torsion test

WP 510.01	Set of 5 torsion specimens, St
WP 510.02	Set of 5 torsion specimens, CuZn
WP 510.03	Set of 5 torsion specimens, Al

Material fatigue with WP 600

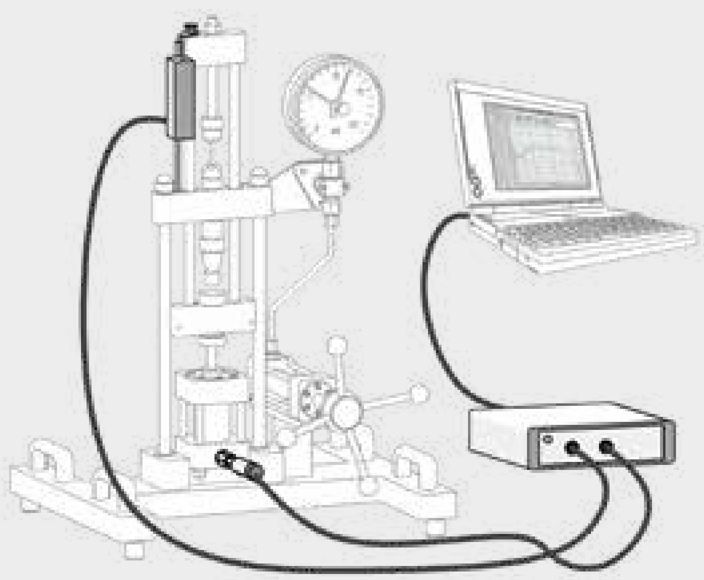
Creep rupture test

WP 600.01	Set of 10 specimens, PE
WP 600.02	Set of 10 specimens, Pb

Accessories

WP 300.09	Laboratory trolley

Systems for data acquisition



GUNT software

- supports various materials tests
- record typical diagrams, e.g. stress-strain diagram, notched bar impact work-temperature diagram
- complete test record according to DIN (tensile and compression test)
- prepare, display and store data
- in WP 140, WP 300, WP 400, WP 410 optionally available
- in WP 310, WP 500, WP 510 included in scope of delivery

WP 300
Materials testing, 20kN

Learning objectives/experiments

- tensile tests
- plot stress–strain diagrams
- Brinell hardness test
- together with the accessories
  - compression tests
  - bending tests
  - cupping tests
  - shear tests
  - testing of plate and coil springs

Description

- **compact, simple experimental unit for basic destructive tests**
- **tensile tests, Brinell hardness test**

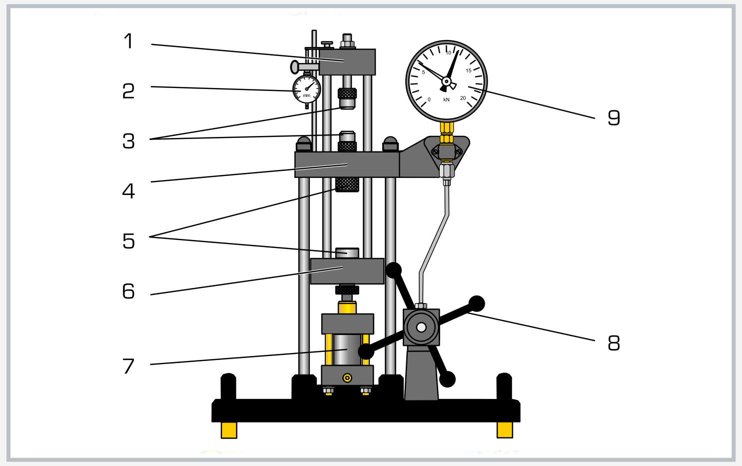
A solid understanding of the properties of materials is essential for technical and scientific professions. This knowledge helps select the suitable material, monitor production and processing and ensure the requirements in terms of a component. The materials test provides the necessary data in a reproducible and precisely quantified manner. The tensile test, bending test and hardness test are all part of classic destructive materials testing.

The range of experiments with WP 300 covers tensile tests and Brinell hardness tests in the base unit.

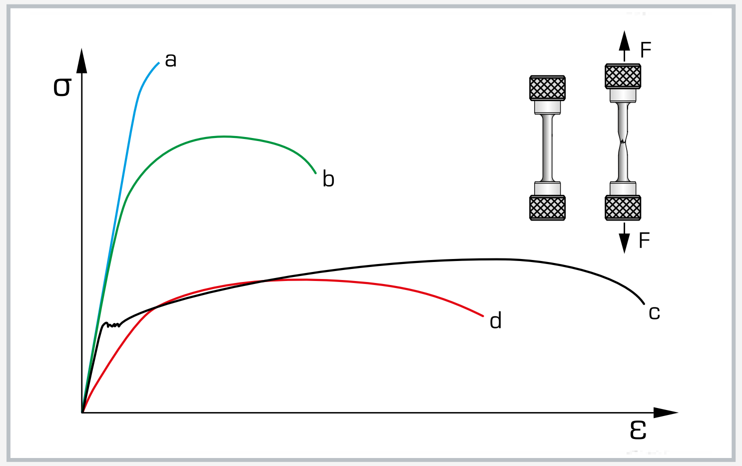
Compression, bending, shear and cupping tests can be conducted using the accessories. Plate and coil springs can also be tested. The experimental unit has been developed specifically for experiments in small groups and is characterised by a clear design, simple operation and accessories that are easy to exchange.

The tensile specimens are clamped between the upper cross member and the crosshead. The hardness specimens are secured between the crosshead and lower cross member. The test force is generated by means of a hand-operated hydraulic system and displayed on a large force gauge with drag indicator. A dial gauge measures the elongation of the specimens.

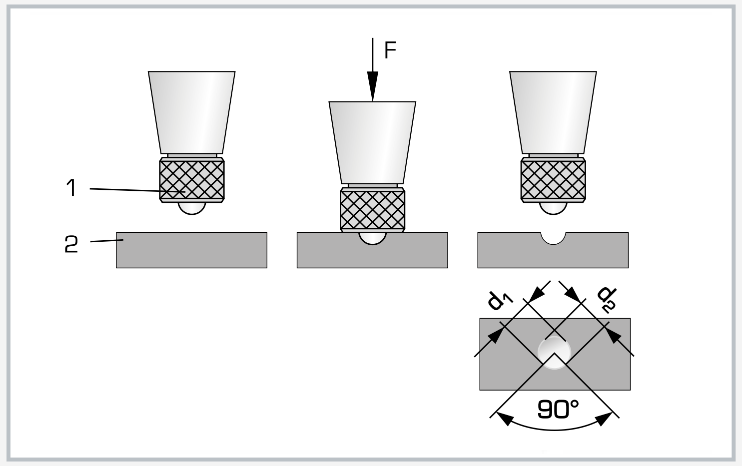
The experimental unit can also be equipped with electronic force and displacement measurement. Using the WP 300.20 system for data acquisition, the measured values for force and displacement can be transferred to a PC where they can be analysed with the software.



1 upper cross-member, 2 dial gauge for elongation, 3 clamp for tensile specimens, 4 crosshead, 5 compression piece and pressure plate, 6 lower cross-member, 7 hydraulic cylinder, 8 hand wheel, 9 force gauge



Stress-strain diagram for various materials: a hardened steel, b tempered steel, c annealed steel, d alloyed aluminium



Brinell hardness test: 1 hardened steel ball, 2 specimen; F test load, d_1 and d_2 dimensions of the impression surface

Specification

[1] classic experiments from destructive materials testing
[2] tensile tests, Brinell hardness test
[3] extensive accessories available for further experiments
[4] generation of tensile and compressive forces
[5] forces generated by hand-operated hydraulic system; no power supply required
[6] force gauge, pointer instrument with drag indicator
[7] dial gauge for determining the elongation
[8] 16 hardness specimens
[9] 16 tensile specimens B6x30 according to DIN 50125
[10] system for data acquisition (WP 300.20) available as an option

Technical data

Test force: max. 20kN
Stroke: max. 45mm
Free installation space for specimens: 165x65mm

16 tensile specimens
- material: 4x Al, 4x Cu, 4x St, 4x CuZn

16 hardness specimens
- LxWxH: 30x30x10mm
- material: 4x Al, 4x Cu, 4x St, 4x CuZn

Sphere for hardness testing: Ø 10mm

Measuring ranges
- force: 0...20kN, graduation: 0,5kN
- travel: 0...20mm, graduation: 0,01mm

LxWxH: 610x500x860mm
Weight: approx. 48kg

Scope of delivery

1 experimental unit
1 device for hardness test
1 force gauge
1 elongation dial gauge
4 sets of tensile specimens (4 pieces each)
4 sets of hardness specimens (4 pieces each)
1 set of instructional material

WP 310
Materials testing, 50kN

The illustration shows WP 310 together with the accessory WP 310.05.

Learning objectives/experiments

- together with the accessories
  - tensile test
  - compression test
  - Brinell hardness test
  - bending test
  - shear test
  - cupping test
  - spring testing

Description

- **hydraulically operated trainer, based on industrial standards**
- **direct generation of tensile and compressive forces**
- **extensive accessories for experiments from destructive materials testing**

A classic discipline of materials testing is the destructive testing method, in which specimens are mechanically tested to failure. The materials test provides data for hardness, rigidity and strength in a reproducible and precisely quantified manner.

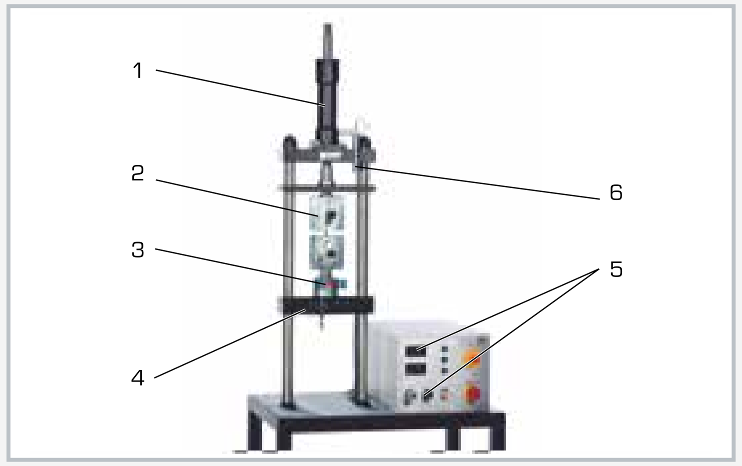
The WP 310 unit, in conjunction with the accessories, offers experiments from destructive materials testing.

The clean layout and simple operation mean the experimental sequence can be observed in all details and phases. The power of the trainer allows tests to be performed on an industrial scale. Material specification data and laws can be verified using self-determined measured values.

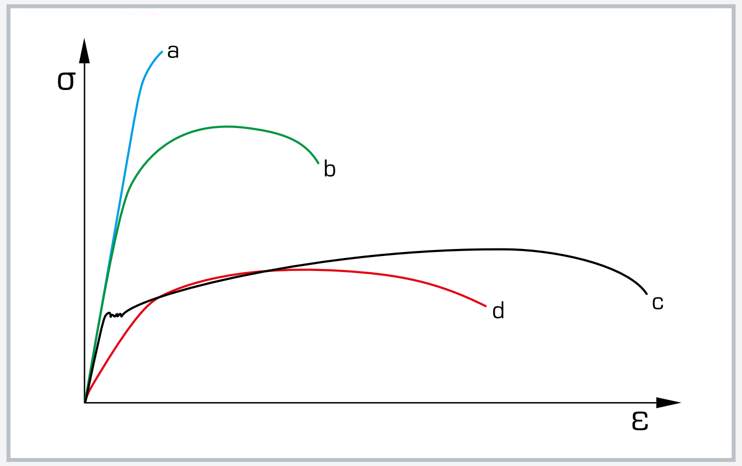
The vertical, hydraulically operated trainer with direct force generation can produce both tensile and compressive forces. The height of the lower cross-member can be adjusted for coarse adjustment. Cylindrical receptacles on the cross-members allow for easy exchange of accessories.

The extensive accessories provide tensile and compression tests, Brinell hardness tests, bending, shear and cupping tests. Plate and coil springs can also be tested. The test load and elongation of the specimen are measured by sensors and are displayed.

The measured values are transmitted directly to a PC where they can be analysed using the software included.



1 hydraulic cylinder for generating tensile and compressive forces, 2 operating area with the accessory WP 310.05, 3 force sensor, 4 adjustable height lower cross-member with lock, 5 displays and controls, 6 displacement sensor



Stress-strain diagram for various materials: a hardened steel, b tempered steel, c annealed steel, d alloyed aluminium

Software screenshot: Brinell hardness test

Specification

[1] hydraulically operated trainer for materials testing, based on industrial standards
[2] generation of tensile and compressive forces
[3] adjustable test load and travel velocity
[4] generation of test load via gear pump and double-acting hydraulic cylinder
[5] force measurement via a strain-gauge full bridge with acoustic overload signal, max. overload 150%
[6] displacement measurement via linear potentiometer
[7] LED displays for force and displacement with tare and maximum-value storage
[8] GUNT software for data acquisition via USB under Windows 7, 8.1, 10
[9] wide range of accessories available

Technical data

Operating area, WxH: 300x925mm
Hydraulic generation of the test load
- test load: 0...50kN
- max. system pressure: 175bar
- max. piston stroke: 150mm
- traverse velocity: 0...425mm/min
- gear pump
  - max. flow rate: 1cm^3/revolution
  - power consumption: 0,55kW

Measuring ranges
- force: 0...50kN
- displacement: 0...150mm

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase; 120V, 60Hz, 1 phase
UL/CSA optional
LxWxH: 1080x830x2300mm
Weight: approx. 330kg

Required for operation

PC with Windows recommended

Scope of delivery

1 trainer
1 GUNT software CD + USB cable
1 set of instructional material

SE 100
Frame for load testing, 400kN

The illustration shows SE 100 together with various accessories

Description

- **load tests on components from steelwork and civil engineering**
- **specially designed for large components at a 1:1 scale**
- **wide range of applications thanks to extensive accessories**

The demands of modern, technically sophisticated designs require a solid understanding of the strength and deformation of components. Different load states can be simulated in load experiments and the reaction to the load recorded and analysed. This makes it possible to demonstrate the load bearing capacity of the design by means of experiment. The SE 100 frame for load tests has been designed specifically for experiments in the fields of steelwork and civil engineering. Large components at a 1:1 scale are studied.

The frame is delivered in prefabricated parts that must be assembled on site. This makes it possible to transport the separate parts through normal doorways. The frame is set up on four adjustable and vibration-damping feet. The generous operating area is designed as a double frame so that longer components can also be studied.

The design of the frame means experiments can be conducted quickly and without complicated assembly. The unit offers a very wide range of possibilities in conjunction with the accessories and the load application device.

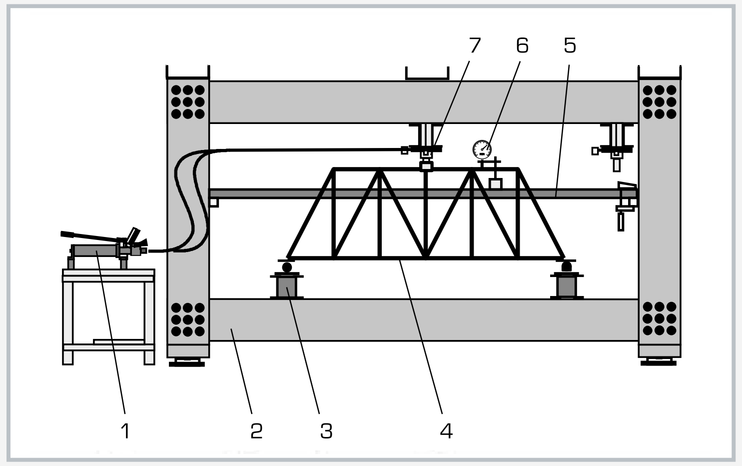
The hydraulically operated load application device, available as accessory SE 100.12, includes a double-action hydraulic cylinder and a hand-operated pump mounted on a table.

The load application device is mounted on rollers and can be positioned at any point on the upper cross-member of the frame. Depending on the experimental setup, it is also possible to use two load application devices (SE 100.02) and therefore generate several forces. The bending is indicated by means of dial gauges, available as accessory SE 100.03.

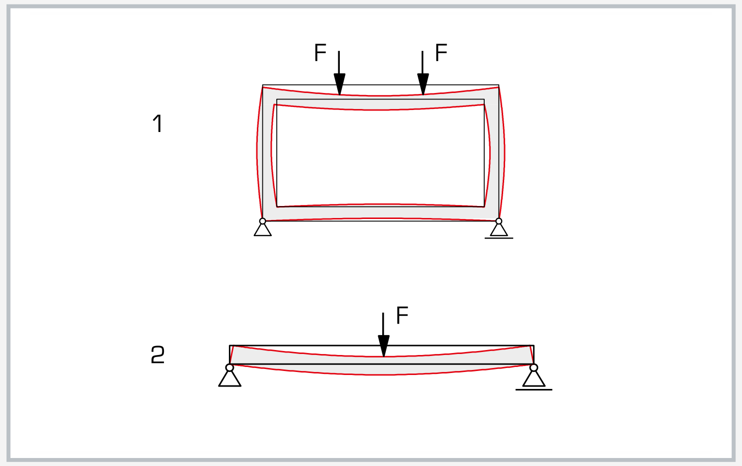
Large components such as reinforced concrete beams, girders or steel frames can be subjected to loads and investigated experimentally. The SE 100.04 accessory is available for experiments on trusses. The forces on typical bars of the truss are recorded by means of strain gauges.

Learning objectives/experiments

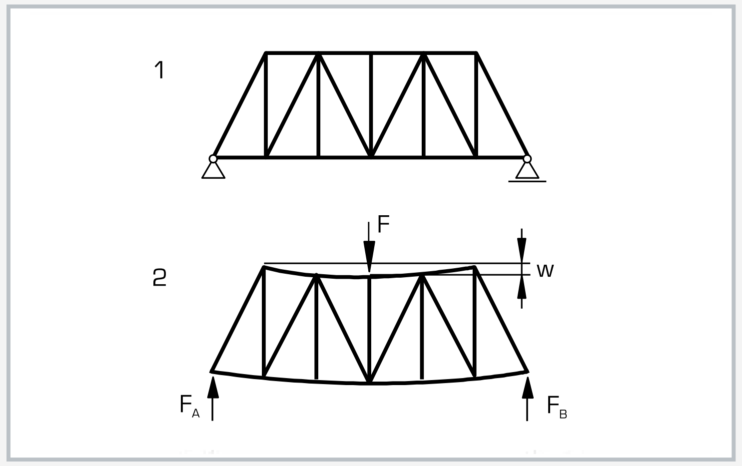
- together with the accessories
  - bending tests
  - load tests
  - compression tests



1 pump for load application device, 2 frame, 3 support SE 100.01, 4 plane truss SE 100.04, 5 measuring traverse, 6 dial gauge SE 100.03, 7 load application device SE 100.02



Suggestions for your own tests with various large components, for example 1 load on frame, 2 load on beam or girder



Bend test on a plane truss SE 100.04; 1 unloaded truss, 2 loaded truss, F test load, F_A and F_B support forces, w bending

Specification

[1] investigation of components at 1:1 scale from steelwork and civil engineering
[2] frame is delivered in parts, transport through normal doorways possible
[3] large operating area, designed as a double frame, also suitable for very long components
[4] mounted on 4 adjustable vibration-damping feet
[5] hydraulically operated load application device for generating compressive forces available as an accessory
[6] optionally available load application device mounted on rollers; SE 100.12 contains 1 load application device, SE 100.02 contains 2 load application devices
[7] load application devices can be positioned at any point on the frame
[8] experiments with different components such as beams, girders or frames possible
[9] plane truss with strain gauge for force measurement available as accessory SE 100.04

Technical data

Frame
- steel profiles: U 400, St52
- frame opening WxH: 4100x1700mm
- clear span in the double frame: 635mm

Test loads
- centre position: max. 300kN
- off-centre: max. 2x 200kN

LxWxH: 5000x1350x2820mm
Weight: approx. 2600kg

Scope of delivery

1 frame of steel profiles

SE 110.48

Bending test, plastic deformation

The illustration shows SE 110.48 in a frame similar to SE 112.

Description

- **observe and determine the transition from elastic to plastic deformation**
- **plot load–extension diagrams**

Mechanical stress, to which design elements are generally exposed, generates stresses in the affected component or the material. If these stresses are too large, there is plastic deformation of the material in addition to the elastic, reversible deformation. The component does not return fully to its original form after the deformation, resulting in a change of shape.

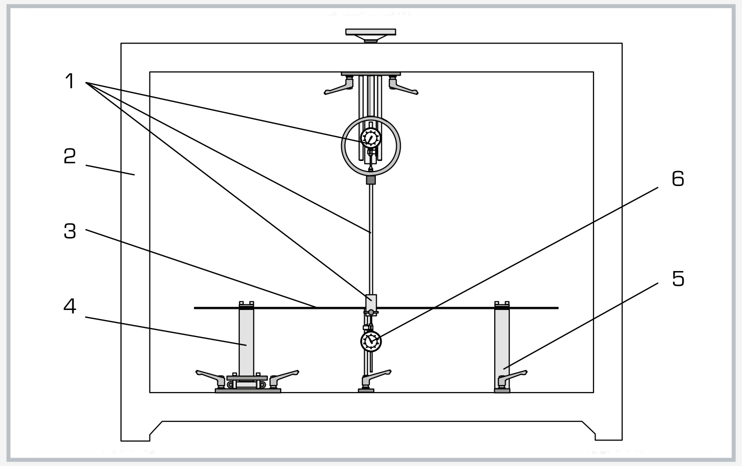
The beam studied in SE 110.48 is mounted on both sides. A movable and a fixed support are included in the scope of delivery to secure the beam. The beam is loaded with a point load. The load application device can be positioned anywhere on the frame. A dial gauge records the deformation. Beams of different materials and profiles are included in the scope of delivery.

The transition from elastic to plastic deformation is observed and determined in the experiment. The values obtained are used to create a load–extension diagram, in which the nonlinear behaviour of the deformation is demonstrated.

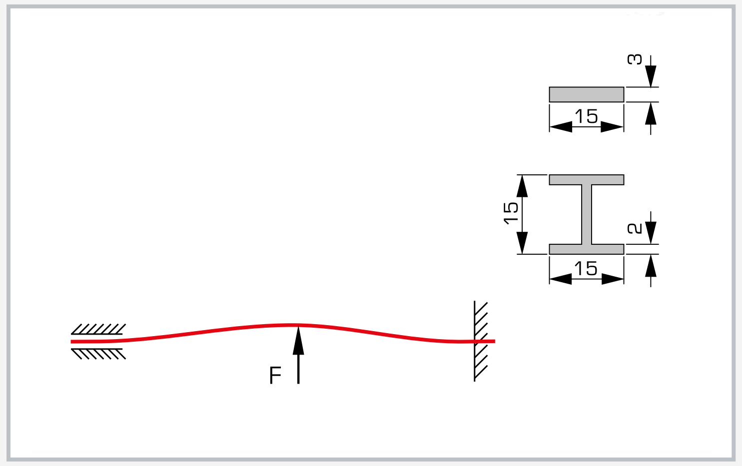
The parts of the experiment are laid out clearly and housed securely in a storage system. The entire experimental setup is constructed in the SE 112 mounting frame.

Learning objectives/experiments

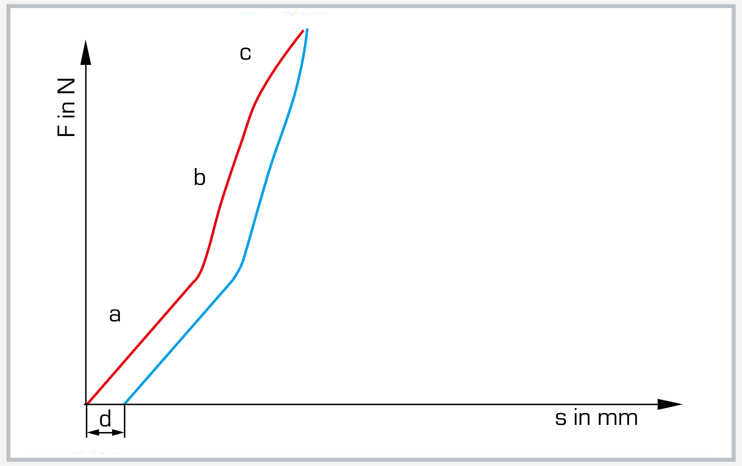
- load on a beam with a point load
- plot a load–extension diagram and determine the nonlinear behaviour
- compare the load and relief curves
- demonstrate the invalidity of the superposition principle in the plastic region



1 load application device, 2 SE 112 frame, 3 beam, 4 movable support, 5 fixed support, 6 dial gauge



Plastic deformation of a beam, both beam profiles included in the scope of delivery



Load-extension diagram for red: load curve and blue: relief curve; a elastic region, b region of non-linear deformation, c plastic range, d permanent deformation; F force, s elongation

Specification

[1] study a beam until plastic deformation
[2] load on the beam from point load
[3] fixed and movable support for supporting the beam
[4] beams of different materials and profiles
[5] dial gauge for recording the deformation
[6] storage system for parts
[7] experimental setup in the SE 112 mounting frame

Technical data

Beams
- 1x 1000x15x3mm, steel
- 1x 1000x15x3mm, aluminium
- 1x H-profile, 1000x15x15x2mm, aluminium

Load application device
- max. load: ±5000N
- max. travel: 100mm

Measuring ranges
- travel: 0...50mm

LxWxH: 1170x480x178mm
Weight: approx. 30kg

Scope of delivery

1 set of beams (3 pieces)
1 load application device
2 supports
1 dial gauge
1 tension device
1 storage system with foam inlay
1 set of instructional material

WP 400
Impact test, 25Nm

Learning objectives/experiments

- determine the notched-bar impact work
- determine the notched-bar impact strength
- analyse the fracture surface characteristics
- plot a notched-bar impact work–temperature diagram
- influence of notch shape, material and specimen temperature on the notched-bar impact work

Description

- **Charpy notched-bar impact test**
- **classic method from destructive materials testing for quality control and analysis of the fracture behaviour of metallic materials**
- **pendulum impact tester based on DIN EN ISO 148-1**

In the field of industrial quality control, the impact test is a widely used test method with which to quickly and easily determine characteristics for a material or component analysis.

The WP 400 experimental unit is a solid-pendulum impact tester based on DIN EN ISO 148-1, designed for the Charpy notched-bar impact test. The clean layout and simple operation mean the experimental sequence can be observed in all details and phases.

In the experiment, the hammer attached to a pendulum arm describes an arc. At the lowest point of the hammer path, the hammer transfers part of its kinetic energy to the notched specimen. The specimen is either destroyed or bent by the impact and pushed between the supports.

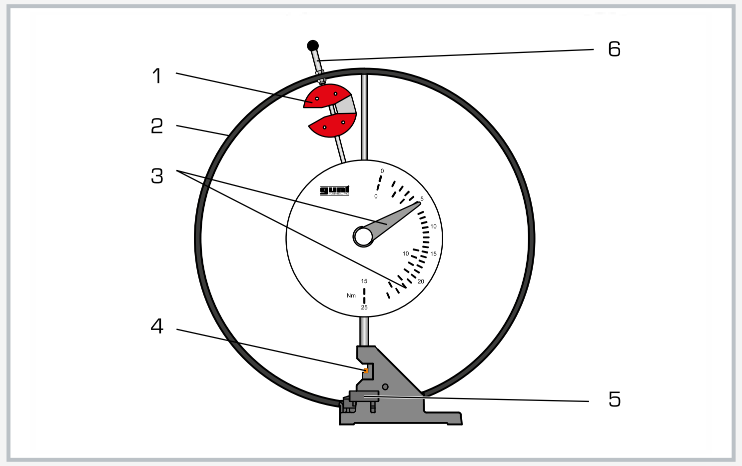
The notched-bar impact work required to deform the specimen is read directly off a large scale. By using the WP 400.20 system for data acquisition, the measured values can be transferred to a PC where they can by analysed with the software.

In order to vary the output energy, the mass of the hammer can be changed by adding or removing weights.

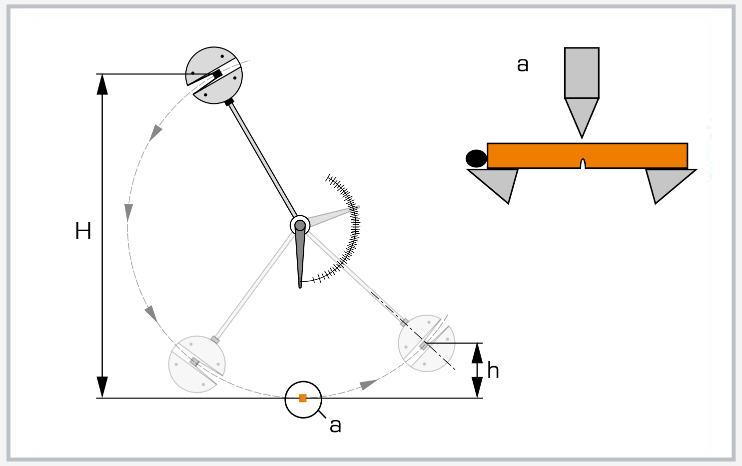
A brake reduces the residual energy of the hammer on each swing until it reaches zero.

A protective ring ensures the experiments can be conducted safely while also fixing the hammer in place. The hammer is triggered with two hands for safer operation. A protective cover for the WP 400.50 operating area is available as an accessory.

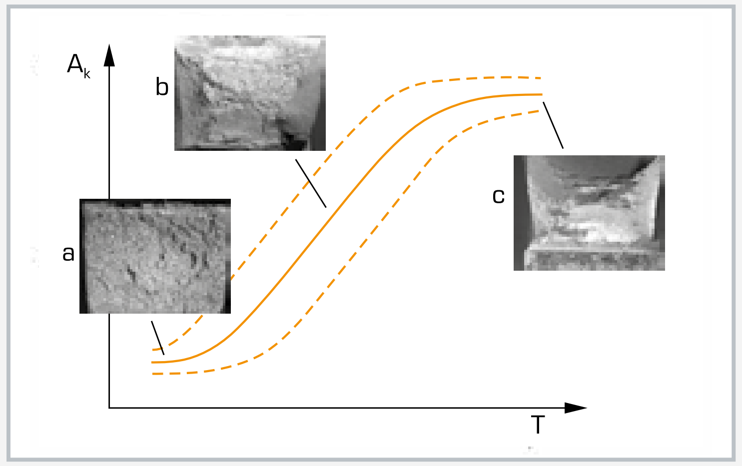
The experimental results allow quality control and an analysis of the fracture behaviour of different metallic materials. Non-metallic specimens can also be used. Specimens with different notch geometries, in different materials and specimen dimensions are included in the scope of delivery.



1 hammer with removable additional weights, 2 protective ring, 3 scale with drag pointer, 4 notched bar impact specimen, 5 two-hand trigger and brake, 6 hammer fixing



Principle of operation of the Charpy notched bar impact test: H height of fall, h height of rise, a hammer and specimen, plan view



Notched bar impact work-temperature diagram with typical fracture surfaces: average-value curve with distribution area, A_k notched bar impact work, T temperature; a depth position with low-deformation fractures, b transition region (steep front) with mixed fractures, c height position with ductile fractures

Specification

[1] classic Charpy notched-bar impact test
[2] pendulum impact tester based on DIN EN ISO 148-1
[3] hammer mass can be varied by adding or removing weights
[4] brake to reduce the residual energy
[5] safe operation thanks to two-hand release of the hammer and protective ring for the operating area
[6] protective cover WP 400.50 available as an accessory
[7] scale for displaying the notched-bar impact work
[8] notched-bar impact specimens according to ISO (U/V notch) and GUNT specimens: automotive steel, tempering steel, structural steel, brass
[9] system for data acquisition (WP 400.20) available as an option

Technical data

Pendulum impact tester
- work capacity
  - 15Nm
  - 25Nm (with extra weights)
- hammer
  - weight: 2,05kg and 3,42kg (with extra weights)
  - extra weights: 4x 0,342kg
  - impact velocity: 3,8m/s
  - head: 745mm

Supports for specimens
- gap: 40mm

Notched bar impact specimens
- LxW: 10x5mm, 10x10mm
- cross-section at the notch root: 10x8 and 10x5mm

Specimen materials
- automotive steel 9SMn28K
- tempering steel C45k
- structural steel S235JRC+C
- brass CuZn40Pb2

LxWxH: 1000x300x1000mm
Weight: approx. 55kg

Scope of delivery

1 experimental unit
1 set of weights
1 set of specimens (90 pieces)
1 set of instructional material

WP 410
Impact test, 300Nm

Learning objectives/experiments

- determine the notched-bar impact work
- determine the notched-bar impact strength
- analyse the fracture surface characteristics
- plot a notched-bar impact work–temperature diagram
- influence of notch shape, material and specimen temperature on the notched-bar impact work

Description

- **Charpy notched-bar impact test with increased work capacity up to 300Nm**
- **pendulum impact tester based on industrial standards / DIN EN ISO 148-1**
- **safe experiments thanks to two-handed release of the hammer and optional protective cage WP 410.50**

In the field of industrial quality control, the impact test is a widely used test method with which to quickly and easily determine characteristics for a material or component analysis.

The WP 410 trainer is a solid-pendulum impact tester based on DIN EN ISO 148-1, designed for the Charpy notched-bar impact test.

The clean layout and simple operation mean the experimental sequence can be observed in all details and phases. The power of the trainer allows tests to be performed on an industrial scale.

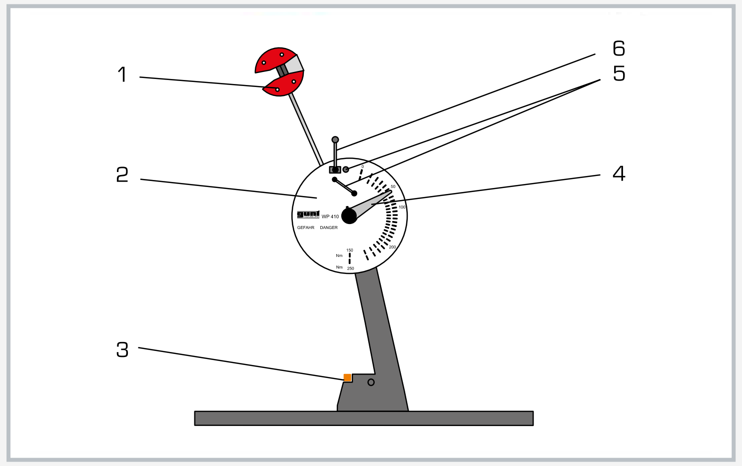
In the experiment, the hammer attached to a pendulum arm describes an arc. At the lowest point of the hammer path, the hammer transfers part of its kinetic energy to the notched specimen. The specimen is either destroyed or bent by the impact and pushed between the supports.

The notched-bar impact work required to deform the specimen is read directly off a large scale. By using the WP 410.20 system for data acquisition, the measured values can be transferred to a PC where they can by analysed with the software.

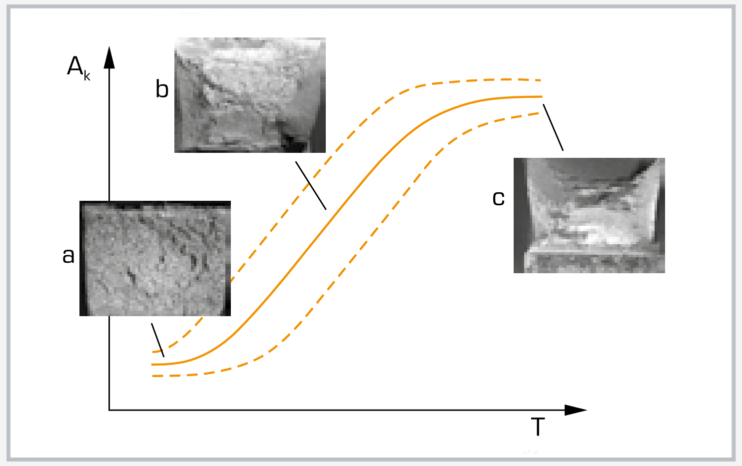
In order to vary the output energy, the mass of the hammer can be changed by adding or removing weights. A brake reduces the residual energy of the hammer.

A protective cover for the operating area allows the experiments to be conducted safely and is available as accessory WP 410.50. The hammer is triggered with two hands for safer operation.

The experimental results allow quality control and an analysis of the fracture behaviour of different metallic materials. Non-metallic specimens can also be used. The scope of delivery includes stainless steel ISO-V notched-bar impact specimens. Specimens made of other materials are available as accessories.



1 hammer with removable extra weights, 2 scale, 3 notched bar impact specimen, 4 drag pointer, 5 two-hand release, 6 brake



Notched bar impact work-temperature diagram with typical fracture surfaces: average-value curve with distribution area, A_k notched bar impact work, T temperature; a depth position with low-deformation fractures, b transition region (steep front) with mixed fractures, c height position with ductile fractures

Protective cover for pendulum impact tester WP 410.50 available as an accessory

Specification

[1] Charpy notched-bar impact test with increased work capacity
[2] pendulum impact tester based on industrial standards / DIN EN ISO 148-1
[3] hammer mass can be varied by adding or removing weights
[4] brake to reduce the residual energy
[5] safe operation thanks to two-handed release of the hammer
[6] protective cover for pendulum impact tester WP 410.50 available as an accessory
[7] scale for displaying the notched-bar impact work
[8] ISO-V notched specimens made of stainless steel, specimens of copper, brass and steel available as accessories
[9] system for data acquisition (WP 410.20) available as an option

Technical data

Pendulum impact tester
- work capacity
  - 150Nm
  - 300Nm (with extra weights)
- hammer
  - weight: 9,9kg and 19,8kg (with extra weights)
  - extra weights: 4x 2,475kg
  - impact velocity: 5,5m/s
  - pendulum length: 840mm
  - angle of fall: 150°

Supports for specimens
- gap: 40mm

Notched bar impact specimens (ISO V and ISO U)
- LxW: 10x10mm

Specimen material
- stainless steel 1.4301

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase; 120V, 60Hz, 1 phase
UL/CSA optional
LxWxH: 800x600x1460mm
Weight: approx. 360kg

Scope of delivery

1 trainer
1 set of weights
1 set of specimens (10 pieces)
1 set of instructional material

WP 500
Torsion test, 30Nm

Description

- **generate the twisting moment by means of a worm gear**
- **measure the twisting moment by means of a strain-gauge measuring shaft**
- **incremental encoder for measuring the twisting angle**

The torsion test is a destructive testing method that studies the plastic behaviour of materials. In practice, components that are twisted in their application (e.g. screws, shafts, axles, wires and springs) are studied with this test method.

The WP 500 experimental unit allows torsion tests in which specimens are subjected to load until they fracture. The clean layout and simple operation mean the experimental sequence can be observed in all details and phases.

In the experiment, metallic specimens are twisted until they are destroyed by a typical shear fracture.

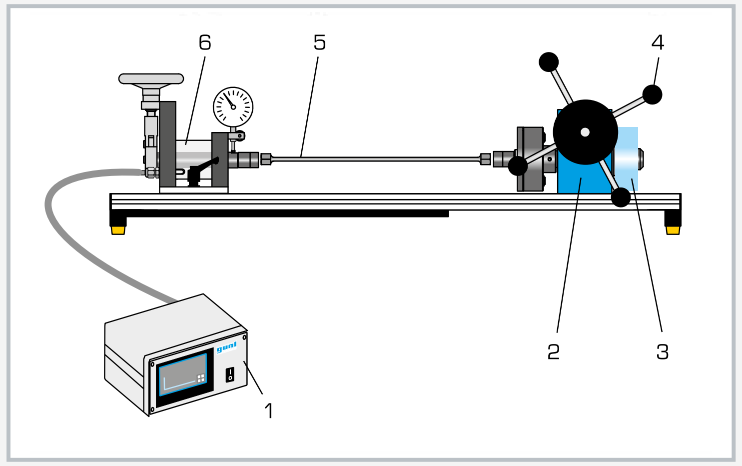
The twisting moment is applied manually by means of a handwheel and a worm gear. The base plate is torsionally reinforced. A transparent protective cover protects against flying fragments.

The effective twisting moment is measured by means of a moment-measuring shaft fitted with strain gauges and can be read directly on a display. The twisting angle is recorded by an incremental encoder and can also be read. The measured values are transmitted directly to a PC where they can be analysed using the software.

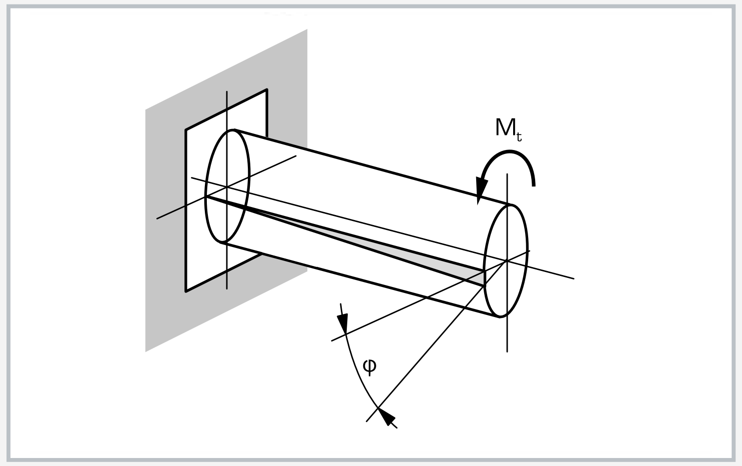
Specimens of different materials and different lengths are included in the scope of delivery. The measuring device can be moved on the rigid frame to adapt to different specimen lengths.

Learning objectives/experiments

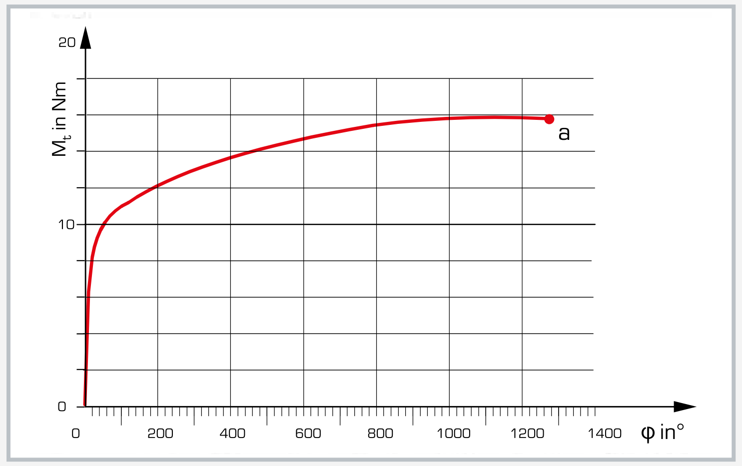
- torsion tests with different materials and load until specimen fracture
- determine the twisting strength
- plot the diagram of twisting moment over twisting angle
- influence of
  - specimen material
  - specimen cross-section
  - specimen length



1 measuring amplifier with display, 2 worm gear, 3 incremental encoder, 4 handwheel for twisting moment, 5 specimen, 6 movable measuring device with strain gauge measuring shaft and compensation unit



Principle of operation of torsion test: M_t twisting moment, φ twisting angle



Torsion test of metallic materials to fracture: M_t twisting moment, φ twisting angle, a specimen fracture

Specification

[1] torsion tests with different metallic specimens to fracture
[2] manual generation of the twisting moment by means of handwheel and worm gear
[3] specify the input angle via handwheel
[4] long and short specimens of steel, aluminium, brass
[5] movable measuring device for different specimen lengths
[6] measure the test moment by means of strain-gauge measuring shaft and measuring amplifier
[7] strain-gauge measuring shaft with compensation for inherent deformation
[8] twisting angle measured by incremental encoder
[9] electronic measuring amplifier with touch panel to display twisting moment and twisting angle
[10] GUNT software for data acquisition via USB under Windows 7, 8.1, 10

Technical data

Max. twisting moment: 30Nm
Loading device, worm gear
- transmission ratio: 1:63

Specimen mount: 2x 17mm, hexagonal
Specimens
- diameter: 6mm
- 4x 75mm, steel
- 4x 75mm, aluminium
- 4x 75mm, brass
- 2x 175mm, steel
- 2x 350mm, steel
- 2x 700mm, steel

Measuring ranges
- twisting moment: 0...30,0Nm
- angle of twist: 0...±3200°, resolution: 0,1°

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase; 120V, 60Hz, 1 phase
UL/CSA optional
LxWxH: 1400x700x500mm (experimental unit)
LxWxH: 230x210x120mm (measuring amplifier)
Weight: approx. 43kg (total)

Required for operation

PC with Windows recommended

Scope of delivery

1 experimental unit
1 measuring amplifier
1 set of specimens (18 pieces)
1 GUNT software CD + USB cable
1 set of instructional material

WP 510
Torsion test 200Nm, motor drive

Description

- **measure the test moment by means of strain gauge**
- **incremental encoder for measuring the twisting angle**
- **four different deformation rates can be configured**
- **experiments based on industrial standards**

The torsion test is a destructive testing method that studies the plastic behaviour of materials. In practice, components that are twisted in their application (e.g. screws, shafts, axles, wires and springs) are studied with this test method.

The WP 510 experimental unit allow torsion tests in which specimens are subjected to load until they fracture. The clean layout and simple operation mean the experimental sequence can be observed in all details and phases. The power of the experimental unit allows tests to be performed on an industrial scale.

In the experiment, metallic specimens are twisted until they are destroyed by typical shear fracture. The twisting moment is applied from a high-ratio reduction gear motor.

A frequency converter offers four different drive velocities in forward and reverse rotation. The base plate is torsionally reinforced. A transparent protective cover protects against flying fragments.

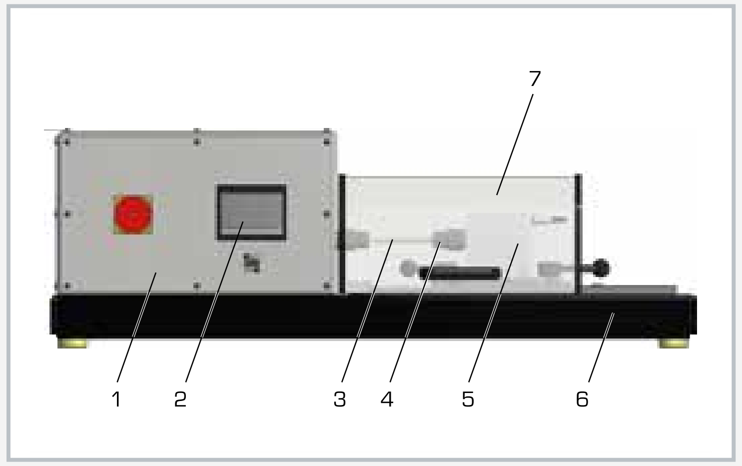
Specimens of different materials and different lengths are included in the scope of delivery. The measuring device can be moved on the rigid frame to adapt to different specimen lengths.

The effective twisting moment (test moment) is measured by means of a moment-measuring shaft fitted with strain gauges and can be read directly on a display. The twisting angle is recorded by an incremental encoder and can also be read. The microprocessor-based instrumentation is well protected in the housing.

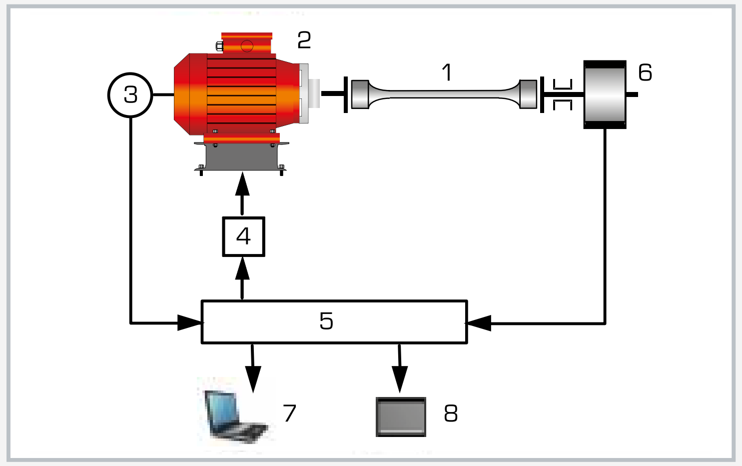
The GUNT software, together with the microprocessor, provides all the advantages of using software to help conduct and analyse the experiments. The unit is connected to the PC via USB.

Learning objectives/experiments

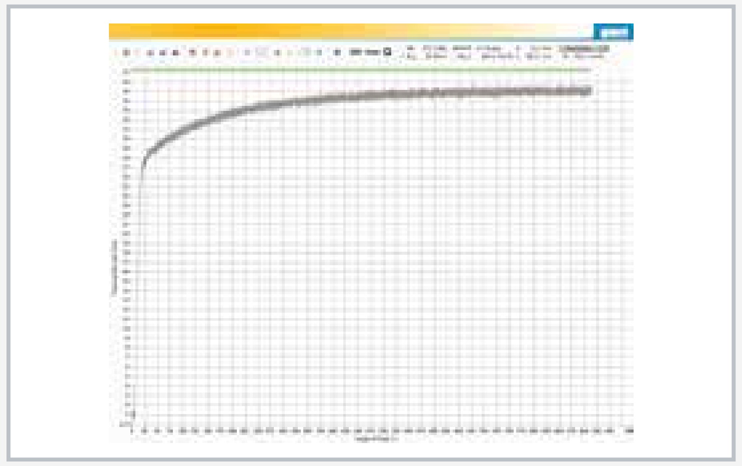
- torsion tests with different materials and load until specimen fracture
- determine the twisting strength
- plot the diagram of twisting moment over twisting angle
- determine the elastic region
- influence of
  - specimen material
  - specimen cross-section
  - specimen length



1 drive unit with gear motor, 2 touch panel for operation and displaying measurements, 3 specimen, 4 specimen holder (commercial 19mm socket), 5 quick-release abutment on guide rails with moment measuring device, 6 rigid base plate, 7 transparent protection



1 specimen, 2 gear motor, 3 incremental encoder, 4 frequency converter, 5 microprocessor, 6 strain gauge measuring shaft, 7 PC, 8 touch panel



Software screenshot: twisting moment over twisting angle

Specification

[1] motor-supported torsion tests with different metallic specimens to fracture
[2] generate the twisting moment by means of worm gear motor; adjustable torsion rates, forward and reverse
[3] worm gear motor, speed controlled by frequency converter
[4] specimens: steel, aluminium, brass
[5] measure the test moment by means of strain-gauge measuring shaft
[6] twisting angle measured by incremental encoder
[7] measured values displayed and controlled via touch panel
[8] microprocessor-based measuring technology
[9] GUNT software for data acquisition via USB under Windows 7, 8.1, 10

Technical data

Worm gear motor
- max. twisting moment: 200Nm
- torsional velocities: 50, 100, 200, 500°/min
- frequency converter with 4 fixed speeds
- motor output: 0,12kW, forward and reverse

Specimens
- diameter: 9mm, length: 100mm
- 3x steel
- 3x aluminium
- 3x brass
- specimen holder: 2x19mm, hexagonal
- possible specimen lengths: max. 300mm

Measuring ranges
- twisting moment: 0...199,9Nm
- angle of twist: 0...±3200°, resolution: 0,1°

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase; 120V, 60Hz, 1 phase
UL/CSA optional
LxWxH: 1120x550x380mm
Weight: approx. 95kg

Required for operation

PC with Windows

Scope of delivery

1 experimental unit
3 set of specimens (9 pieces)
1 GUNT software CD + USB cable
1 set of instructional material

WP 140
Fatigue strength test

Description

■ **different specimens show the influence of notching and surface quality**
■ **continuous adjustment of the load amplitude**
■ **automatically shuts down when the specimen fractures**

Moving components and machine parts are often exposed to periodically fluctuating loads. Even if the dynamic load is far below the static load capacity, this load can lead to fracture of the component after a long time because of material fatigue. The fatigue strength and design strength of components are determined in fatigue strength tests or endurance tests.

The WP 140 trainer demonstrates the basic principles of fatigue strength testing and the creation of a Wöhler diagram. The clean layout and simple operation mean the experimental sequence can be observed in all details and phases. In the experiment, a cantilever-mounted and rotating cylindrical specimen is subjected to a single force. The load on the specimen corresponds to a cantilever bending beam. The specimen is subjected to a pure reverse bending stress and breaks after a certain number of load cycles because of material fatigue.

The necessary force is generated in the load application device by means of a spring balance and a movable support. The load amplitude can be adjusted continuously using the preload of the spring balance by means of a threaded spindle. An electronic counter registers the number of load cycles and displays it digitally. The impulse for the counter is provided by an inductive proximity switch on the motor coupling. The counter can also be used to measure the speed.

When the specimen breaks, the stop switch stops the electric motor automatically. A protective cover protects against flying fragments.

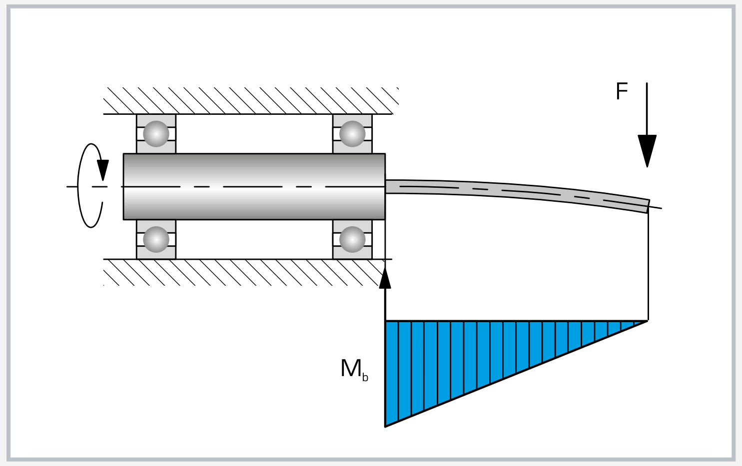
Specimens with various fillet radii are included in the scope of delivery to demonstrate the notching effect and the influence of the surfaces.

By using the WP 140.20 system for data acquisition, the measured values can be transferred to a PC where they can by analysed with the software.

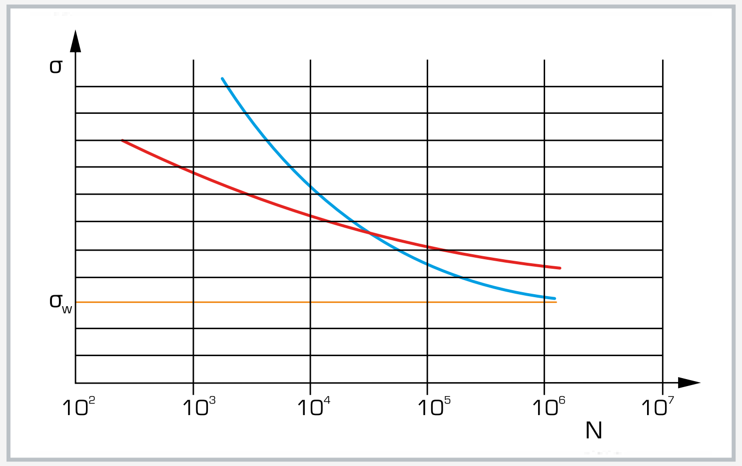
Learning objectives/experiments

■ fatigue strength of bars under reverse bending stress
■ influence of different fillet radii and surface qualities on the fatigue strength
■ Wöhler diagram

1 protective cover, 2 electric motor, 3 switch box, 4 tool, 5 specimens, 6 bearing, 7 clamped specimen, 8 load application device with spring balance and hand wheel



Functional principle of a fatigue strength test: cantilever mounted rotating specimen, loaded with a single force; F force, M_b bending moment



Woehler diagram for two different materials N: number of load cycles, σ: stress load on the specimen
With increasing number of cycles, the permissible load of a material asymptotically approaches the fatigue strength σ_W.

Specification

[1] basic principles of fatigue strength testing
[2] driven by electric motor
[3] automatically shuts down when the specimen fractures
[4] load application device with sliding movable support, threaded spindle with hand wheel, spring balance
[5] steel cylindrical specimens, various fillet radii
[6] speed measured by contactless inductive speed sensor or electronic counter for load cycles
[7] digital counter display
[8] protective cover for safe operation
[9] system for data acquisition (WP 140.20) available as an option

Technical data

Electric motor
■ speed: 2800min^{-1}
■ power: 0,37kW

Load force
■ 0...300N

Electronic load counter
■ 8-digit
■ switchable to indicate speed

Specimens
■ material: steel Ck35
■ 3 different fillet radii

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase; 120V, 60Hz, 1 phase
UL/CSA optional
LxWxH: 840x410x600mm
Weight: approx. 31kg

Scope of delivery

1 experimental unit
1 set of specimens (9 pieces)
1 set of instructional material

WP 600
Creep rupture test

Description

- **typical phenomena of creep processes**
- **experiments at or below room temperature are possible**

Components that are subjected to long-term constant loads deform plastically. This material behaviour is called creep. The creep rupture test is a destructive test method for determining the material behaviour (creep) at constant test temperature (room temperature and below) and after prolonged exposure to a constant load.

The WP 600 experimental unit demonstrates typical phenomena such as phases of different creep rates or temperature-dependent creep behaviour. The clean layout and simple operation mean the experimental sequence can be observed in all details and phases. Lead and plastic specimens are used in order to achieve acceptable creep rates at room temperature.

Experiments can also be conducted below room temperature by means of a transparent temperature-controlled box with storage elements.

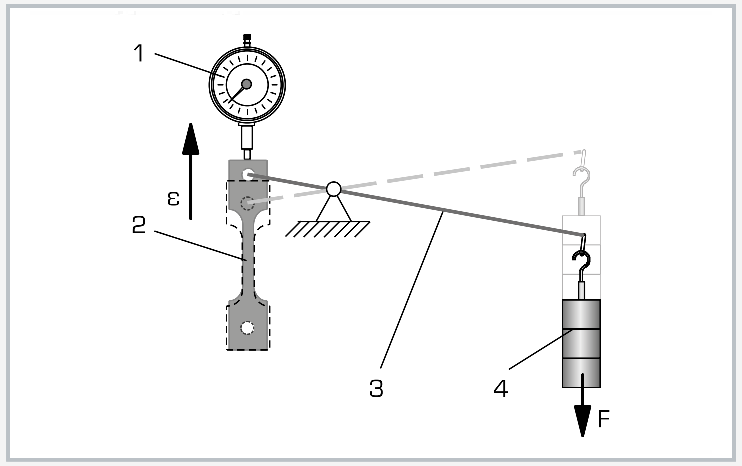
In the experiment, the specimen is subjected to a constant tensile load at a given, constant temperature. The tensile load is generated by a lever and stepped weights. The specimen holders are equipped with knife-edge bearings to avoid bending stresses on the specimen. An adjustable stop protects the dial gauge at fracture of the specimen and prevents the loads impacting the experimental unit.

The elongation of the specimen over time is recorded by a dial gauge and a stopwatch and represented in a strain–time diagram as the so-called creep curve.

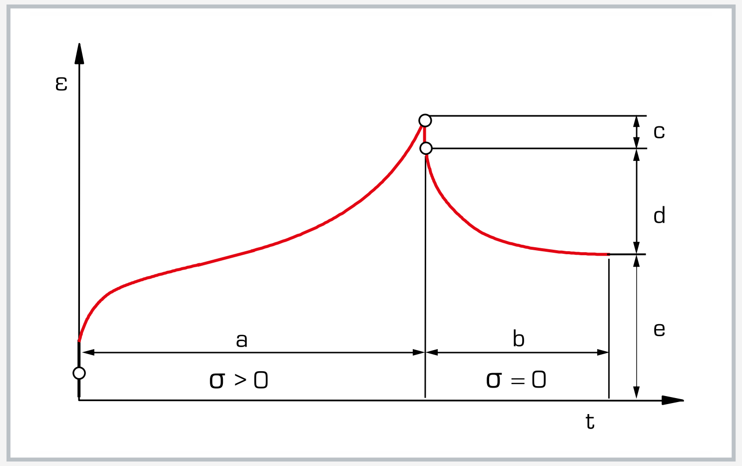
Learning objectives/experiments

- creep in specimens of various materials
- record a strain–time diagram (creep curve)
- influence of temperature and load on the creep
- load and recovery in plastics

1 thermometer for temperature-controlled box, 2 storage element for cooling the specimen, 3 clamped specimen, 4 specimens, 5 weight, 6 adjustable stop for the lever, 7 lever, 8 dial gauge



Principle of operation of the creep rupture test: 1 dial gauge, 2 specimen, 3 lever for load transfer, 4 weight; F force, ε strain



Strain-time diagram (creep curve) of plastic: a load, b recovery, c elastic recovery, d plastic recovery, e permanent deformation, ε strain, σ stress, t time

Specification

[1] investigation of creep behaviour of different materials in creep rupture test
[2] constant load on the specimen via lever arm and stepped weights
[3] flat lead and plastic (PE) specimens
[4] experiments at or below room temperature are possible
[5] transparent temperature-controlled box with storage elements for cooling the specimen
[6] dial gauge for determining the elongation
[7] stopwatch to record time

Technical data

Specimens
- LxW: 25x5mm, thickness 2mm
- 10x lead
- 10x plastic (PE)

Weights
- 1x 1N (hanger)
- 2x 5N
- 3x 2N
- 3x 1N
- 2x 0,5N

Measuring ranges
- tension: 5...25N/mm^2
- travel: 0...10mm, graduation: 0,01mm
- temperature: -50...300°C

LxWxH: 700x350x510mm
Weight: approx. 23kg

Scope of delivery

1 experimental unit
1 set of specimens (20 pieces)
1 set of weights
1 stopwatch
1 temperature-controlled box with 2 storage elements and 1 thermometer
1 set of instructional material

Tribology and corrosion

Tribology

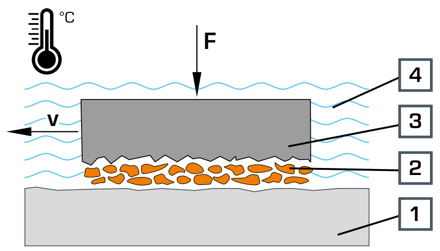
Tribology is the science and technology of interacting surfaces in relative motion. The application of tribology in engineering is used to study friction, wear and lubrication. These studies extend to all areas of development, engineering design, production and maintenance of mechanical motion systems. Wear processes are analysed by means of a so-called tribological system and are described by "systemic" loss variables. A tribological system contains all elements such as components and substances that are involved in a tribological load, as well as their properties. Material components such as body, counter body, intermediate substance and ambient medium form the system structure. The input variables and disturbance variables are summarised as collective stresses.

Collective stresses

Input variables
- type of motion
- motion sequence
- load
- velocities
- temperatures
- load duration

Disturbance variables
- external mechanical vibrations
- radiation

Structure of the tribological system
- elements (**1** body, **2** intermediate substance, **3** counter body, **4** ambient medium)
- material and geometric properties
- interaction between the elements

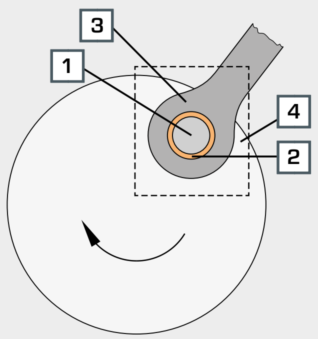


Output variables
- force
- torque
- speed
- mechanical energy
- material variables

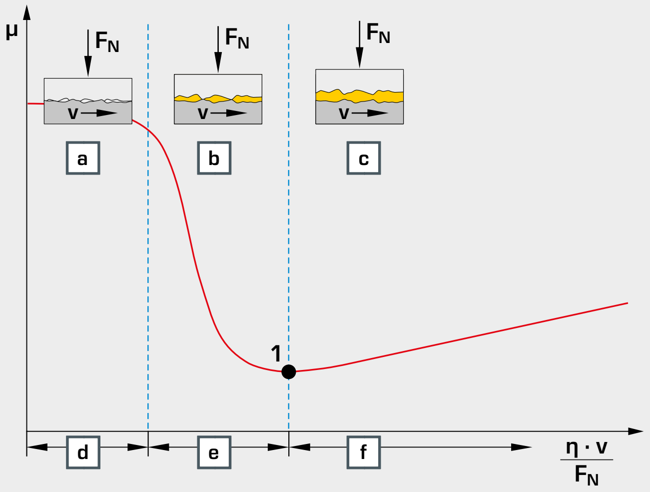
Loss variables
- friction
- heat
- vibrations
- emissions
- wear
- material erosion

Technical function of the tribological system

Tribological system, represented using the example of bolts / bearing shell



1 body, **2** intermediate substance, **3** counter body, **4** ambient medium



Stribeck curve for hydrodynamic friction

μ coefficient of friction, **n** speed, **F_N** load, **v** velocity, **η** viscosity, **a** dry friction, **b** mixed friction, **c** fluid friction, **d** boundary lubrication, **e** thin-film lubrication, **f** fluid lubrication, **1** release point

In the analysis of tribological systems, loss variables such as coefficient of friction, frictional forces and frictional vibrations are determined by suitable measuring methods. The change of an input variable or disturbance variable can change the friction and wear behaviour significantly. Experiments are required in order to investigate dependencies of loss variables.

The Stribeck curve gives a good overview of occurring friction states, such as in slide bearings. The relationships between coefficient of friction, friction pressure and bearing force are shown clearly. With increasing velocity, the lubricant film thickness increases and the regions of dry friction, mixed friction and fluid friction, in which the surfaces are completely separated by the lubricating film, are passed through in sequence.

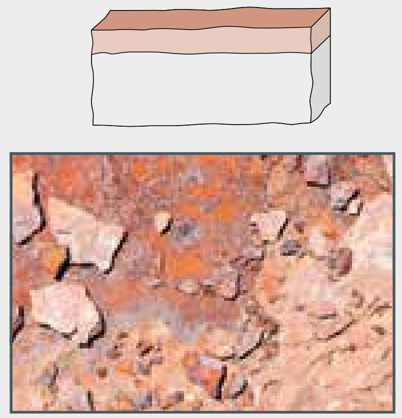
The transition from mixed friction to fluid friction is known as the release point. The lowest wear occurs in the region of fluid friction.

Corrosion

Corrosion refers to the reaction of a metallic material to its environment, which causes a measurable change in the material. This can lead to impairment of the function of a metal component or a whole system.

The form of the material changes due to corrosion

Surface erosion, uniform erosion of the workpiece surface



Pitting corrosion, crater-shaped or pinhole-like depressions that undermine the surface

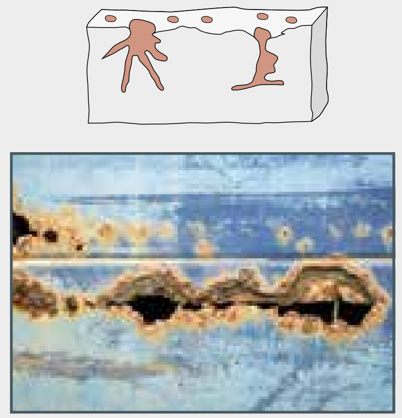
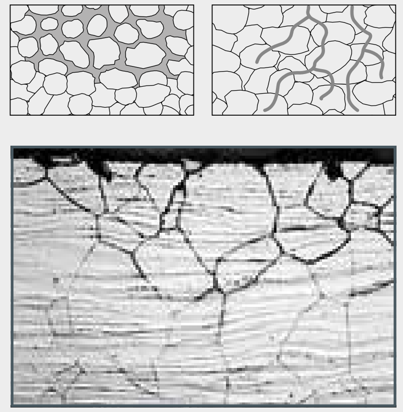
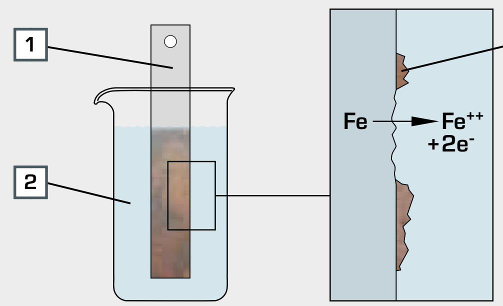


Figure left and below: intergranular corrosion along the grain boundaries.
Figure right: transgranular corrosion, transverse through the grains



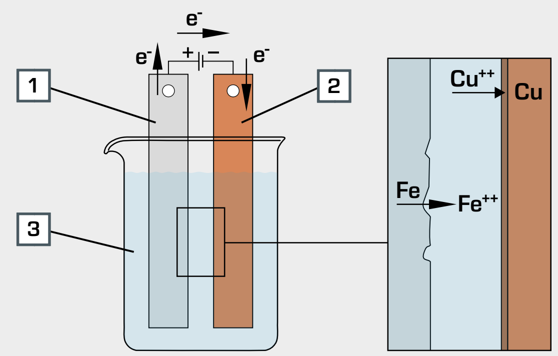
Processes during corrosion

The environmental conditions of the material are significant for corrosion. Essentially, these are gases from the surrounding atmosphere and liquids. Solutions can be electrolytes (ion-conducting liquids). In metals, corrosion is caused primarily by electrochemical or chemical processes.



Oxygen corrosion: a direct electron exchange takes place between iron and oxygen-enriched water. The iron bonds with the oxygen to form iron oxide.

1 electrode (iron Fe), **2** electrolyte enriched with oxygen (water), **3** iron oxide, **Fe^{++}** iron ion, **e^-** free electron



Electrochemical corrosion occurs through the formation of galvanic elements. If two different metals come into contact, an electrical current flows in the presence of an electrolyte. This dissolves base metal. More or less current flows depending on the metals present, and destruction takes place.

1 anode (iron Fe), **2** cathode (copper Cu), **3** electrolyte (copper sulphate $CuSO_4$), **Cu^{++}** copper ions, **e^-** electron, **Fe^{++}** iron ion

TM 260

Drive unit for tribological investigations

Description

- **base module for studying various cases of sliding and rolling friction**
- **contact force by means of weights and lever**
- **electronic measurement of the frictional force between friction partners**

Tribology studies friction, wear and lubrication. Friction occurs when two solids are in contact with each other and their movement is impeded. If material is lost progressively during this process, it is referred to as wear. Lubricants are used to minimise friction and wear.

The TM 260 drive unit, together with the experimental units TM 260.01 to TM 260.06, offer a complete course with a series of experiments to study tribological phenomena. Various rolling and sliding cases can be demonstrated in the classroom or studied in the laboratory. The parameters of a tribological system are recorded and analysed. A comprehensive range of friction pairings makes it possible, among other things, to represent how the frictional force is independent of the contact area.

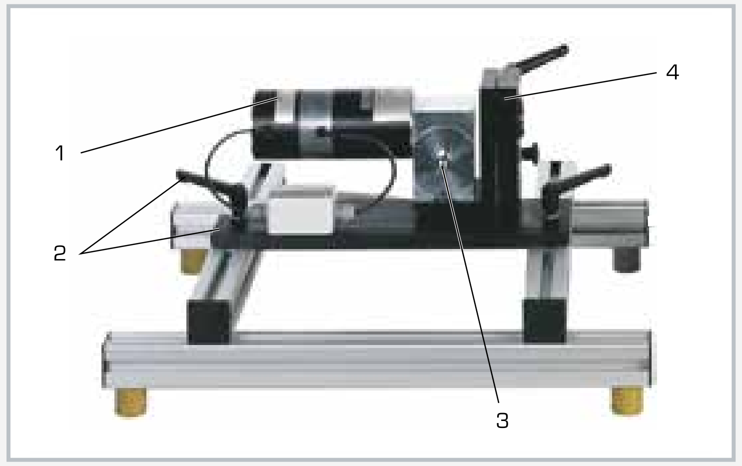
The TM 260 units comprise a frame on which the drive unit is mounted together with an experimental unit and a display and control unit. Quick-action chucks make it quick and easy to assemble. The drive unit has a pivotable motor block bearing. This allows the drive shaft to be installed horizontally or vertically. The speed of the DC motor is continuously adjustable and is detected by means of an incremental encoder. The frictional forces are measured by a force sensor in each experimental unit.

The display and control unit shows frictional force and speed, the latter of which can be adjusted continuously.

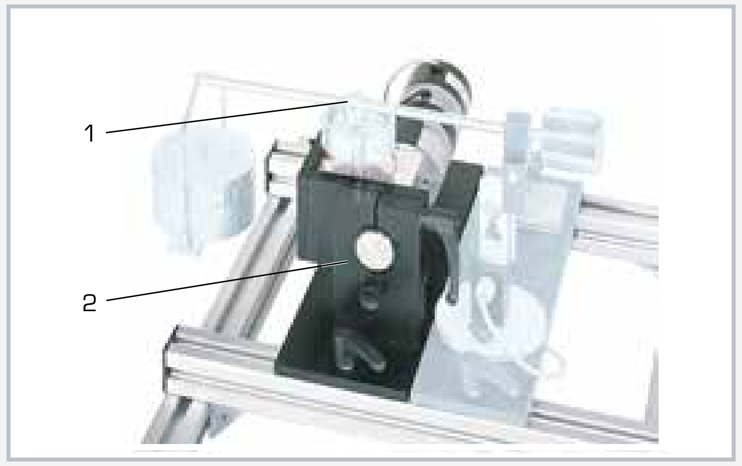
The following experiments can be conducted: Rolling friction in friction wheels (TM 260.01), Elasto-hydrodynamic behaviour (TM 260.02), Dynamic friction in a pin on a disk (TM 260.03), Frictional vibrations (TM 260.04), Dynamic friction in a cylindrical pin on a roller (TM 260.05), Pressure distribution in journal bearings (TM 260.06).

Learning objectives/experiments

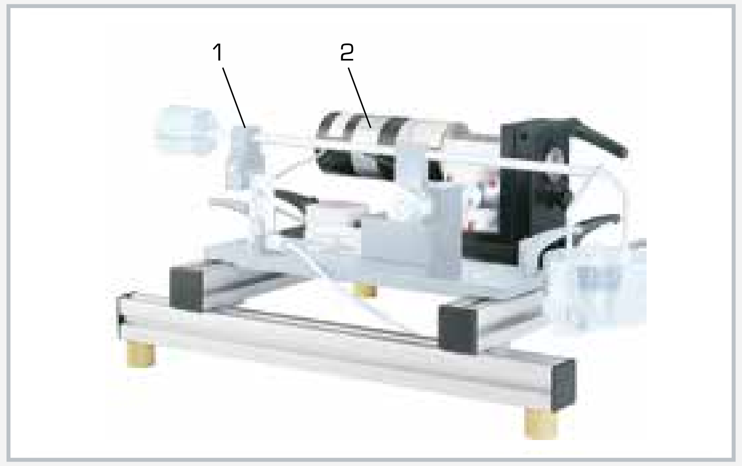
- together with the experimental units TM 260.01 to TM 260.06
  - rolling friction of two disks with slip
  - elasto-hydrodynamic behaviour (EHD theory) in rolling friction of a sphere against a flat surface
  - wear test: pin against disk
  - wear test: friction wheel experiment
  - frictional vibrations and slip–stick phenomenon
  - pressure distribution in the journal bearing



1 motor and gear, 2 quick-action chuck, 3 drive shaft, 4 pivotable drive



1 TM 260.03 experimental unit studies a tribological system, consisting of a pin and disk, which slide against each other, 2 TM 260 drive unit



1 TM 260.05 experimental unit studies a tribological system, consisting of a cylindrical pin and a roller, which slide against each other (point contact), 2 TM 260 drive unit

Specification

[1] base module with drive unit and display and control unit for studying tribological phenomena
[2] horizontal or vertical position of the drive shaft by means of pivotable motor block
[3] various experimental units available as accessories
[4] drive unit and experimental units secured by quick-action chucks
[5] drive unit comprising DC motor with worm gear
[6] speed of the DC motor is continuously adjustable
[7] speed measured by incremental encoder
[8] frictional force measured by force sensor
[9] force and speed displayed on display and control unit

Technical data

DC motor
- rated speed: 3000min^{-1}
- torque: 18,5Nm

Worm gear: ratio 15:1
- operating speed: 0...200min^{-1}, electronically controlled

Measuring ranges
- force: 0...50N
- speed: 0...200min^{-1}

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase; 120V, 60Hz, 1 phase
UL/CSA optional
LxWxH: 500x450x280mm (base module)
Weight: approx. 10kg
LxWxH: 360x330x170mm (display and control unit)
Weight: approx. 6kg

Scope of delivery

1 base module
1 display and control unit
1 set of cables
1 set of instructional material

TM 260.01

Rolling friction in friction wheels

The illustration shows TM 260.01 on the TM 260 frame.

Description

- **frictional forces between two rolling friction wheels**
- **how slip affects the frictional force**
- **use of different lubricants possible**

In bearing and drive technology, dynamic friction occurs at the sliding and rolling points, which leads to power losses in the technical systems. Dynamic friction is differentiated into sliding, rolling and spinning friction. In dynamic friction, there is relative translation between the two bodies. Rolling friction occurs when two bodies roll on each other without sliding. In rolling friction, the rolling motion is superposed with a smaller sliding friction, known as slip. Rolling friction is therefore a combination of rolling and dynamic friction.

The tribological system in TM 260.01 allows a clear representation of the rolling friction and an analysis of the frictional forces. The experimental unit comprises two friction wheels, pairing the materials aluminium and rubber at the contact points.

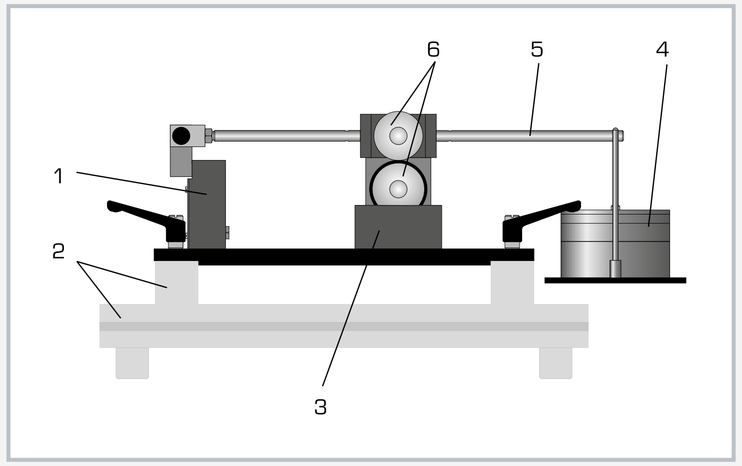
The slip between the friction wheels is kept constant at 4% by a gear unit. The contact force can be adjusted gradually up to a maximum of 80 N by means of a lever. The experimental unit includes a tank that supplies lubricant. Different lubrication conditions can be studied, such as dry friction, water or oil lubrication.

The TM 260 drive unit is required in order to conduct experiments. The experimental unit is mounted quickly and easily on the frame of the drive unit with quick-action chucks. The driving wheel is driven by a clampable coupling between drive unit and gear unit. The display and control unit of the drive unit shows frictional force and speed and allows the continuous adjustment of the speed.

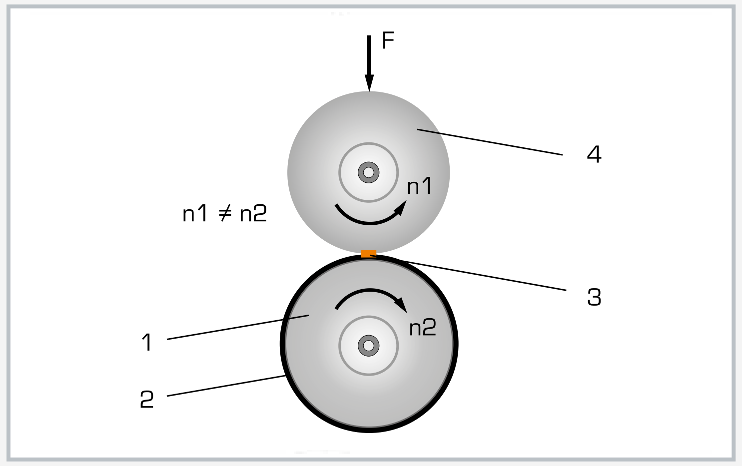
The frictional force and the coefficient of friction can be determined in experiments. The frictional forces are measured by a force sensor.

Learning objectives/experiments

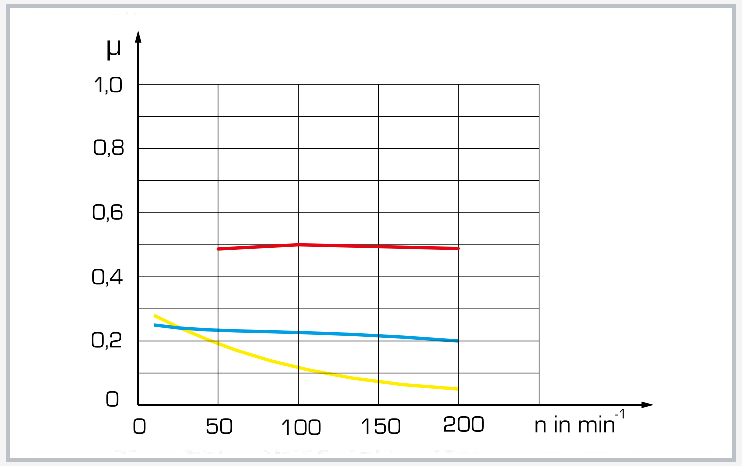
- together with the drive unit
  - determine the frictional forces as a function of load, lubrication and operating speed
  - how slip affects the frictional force
  - determine the coefficients of friction



1 force sensor, 2 frame of TM 260, 3 tank for lubricant, 4 weight, 5 load application device lever, 6 friction wheels



Tribological system using the example of friction wheels pairing aluminium and rubber:
1 driving friction wheel as main body, 2 rubber ring, 3 lubricant as intermediate substance, 4 driven wheel as counter body; F force, n speed



Coefficients of friction for different lubrication at constant load; μ coefficient of friction, n speed, red: dry friction, blue: water lubrication, yellow: oil lubrication

Specification

[1] frictional forces in two rolling friction wheels
[2] quick and easy assembly of the experimental unit on the frame of the drive unit
[3] driving wheel is driven by a clampable coupling between drive unit and gear unit
[4] slip between friction wheels kept constant at 4% by means of gear unit
[5] load on the friction wheels via lever arm and stepped weights
[6] friction wheels materials pair: aluminium/rubber
[7] use of different lubricants
[8] frictional force measured by force sensor
[9] displays of force and speed and speed adjustment on the drive unit

Technical data

Load application device
- max. load: 80N
- lever arm ratio: 2:1

Friction wheels
- Ø=49mm
- Ø=45mm, incl. rubber ring

Gear ratio
- i: 0,96, slip approx. 23%

Force sensor for frictional force
- 0...50N

Weights
- 1x 5N (hanger)
- 1x 5N
- 1x 10N
- 1x 20N

LxWxH: 480x250x150mm
Weight: approx. 7kg

Scope of delivery

1 experimental unit
2 friction wheels
1 set of weights
1 set of instructional material

TM 260.02
Elasto-hydrodynamic behaviour

Learning objectives/experiments

- together with the drive unit
  - determine the thickness of the lubricating film at the contact point of a sphere with a plane surface – compare with theoretical value
  - study the effect of load and speed on the thickness of the lubricating film

Description

- **elasto-hydrodynamic behaviour between the sphere and rotating-glass-plate friction pair**
- **investigation of the thickness and shape of the lubricating film**

Elasto-hydrodynamic lubrication occurs in roller bearings, gear wheels and cam followers, whose contact surfaces are subjected to high loads. These surfaces are elastically deformed because of high contact pressures. The theory of elasto-hydrodynamics (EHD theory) takes into consideration the elastic deformation of the bodies in contact with each other and provides a basis for calculating the influence of lubrication on damage to gears and roller bearings.

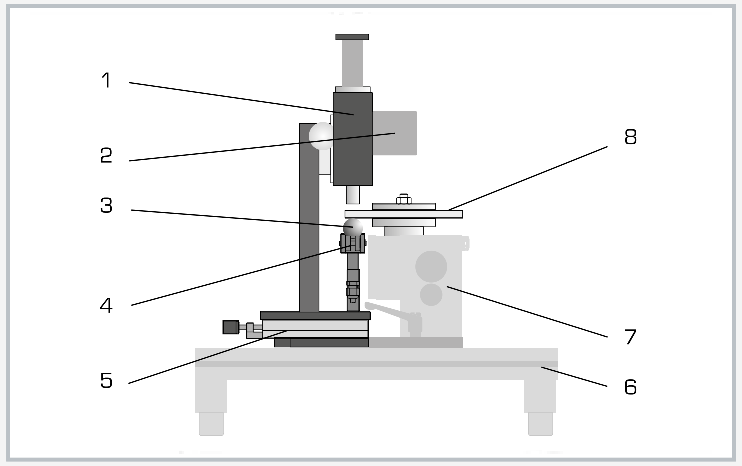
The tribological system in TM 260.02 allows a clear representation of the elasto-hydrodynamic behaviour of lubricating film layers.

To do this, the lubricating film between a sphere and a glass plate is determined and studied using a reflected-light microscope. The experimental unit contains a rotating glass plate and a steel sphere as the friction pair. The steel sphere is pressed against the glass plate from underneath. The contact force between the friction partners can be adjusted continuously by means of a lever. A lubricating film is located between the sphere and glass plate at the contact point. The glass plate is plane-parallel and dielectric coated. The surface of the hardened steel ball is polished. The reflected-light microscope stands on an adjustable xy cross table and has a focus drive.

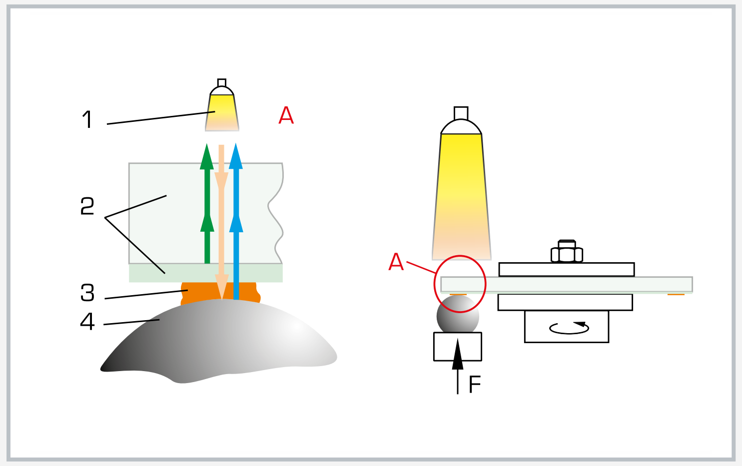
The TM 260 drive unit is required in order to conduct experiments. The experimental unit is mounted quickly and easily on the frame of the drive unit with quick-action chucks.

The glass plate is driven by a clampable coupling between drive unit and gear unit. The display and control unit of the drive unit shows contact force and speed and allows the continuous adjustment of the speed.

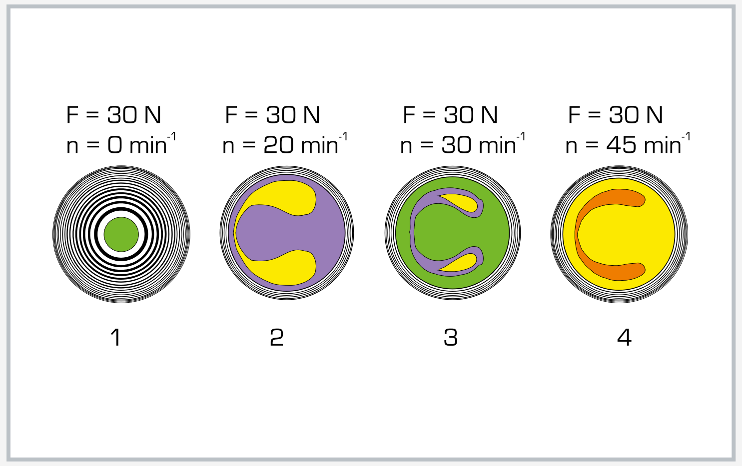
In the experiment, light waves from the reflected-light microscope pass through the glass plate and the lubricating film and are reflected by the surface of the steel sphere. The light waves are refracted in the lubricating film, making colour interference fringes visible. The wavelength of light increases or decreases with the variable thickness of the lubricating film. The thickness of the lubricating film is determined visually by means of the colour of the interference fringes created. The contact force is measured by a force sensor.



1 reflected light microscope, 2 halogen lamp, 3 steel sphere, 4 load application device, 5 cross table, 6 frame of TM 260, 7 drive unit from TM 260, 8 glass plate



Determine the thickness of the lubricating film by optical interference: 1 halogen lamp, 2 glass plate with dielectric coating, 3 lubricating film, 4 steel sphere; arrows orange: incident light, green: dielectric coating reflects 30% of the light, blue: steel sphere reflects the remaining light



Effect of lubricating film thickness on speed: 1 static case, 2 to 4 increase in lubricating film width (lubricating oil ISO VG 100)

Specification

[1] elasto-hydrodynamic behaviour of a lubricating film layer between sphere and rotating glass plate
[2] quick and easy assembly of the experimental unit on the frame of the drive unit
[3] determine the thickness of the lubricating film by optical interference
[4] glass plate is driven by a clampable coupling between drive unit and gear unit
[5] hardened steel sphere, polished
[6] rotating plane-parallel glass plate with dielectric coating
[7] continuous load on the sphere via lever arm
[8] load measured by force sensor
[9] displays of force and speed and speed adjustment on the drive unit

Technical data

Load application device
- max. load: 150N
- lever arm ratio: 3:1

Sphere
- diameter: 25,4mm
- hardened steel, polished

Glass plate
- diameter: 150mm, plane-parallel
- coating: BK 7, dielectric, R=30%

Microscope
- magnification: x50
- halogen lamp: 10W

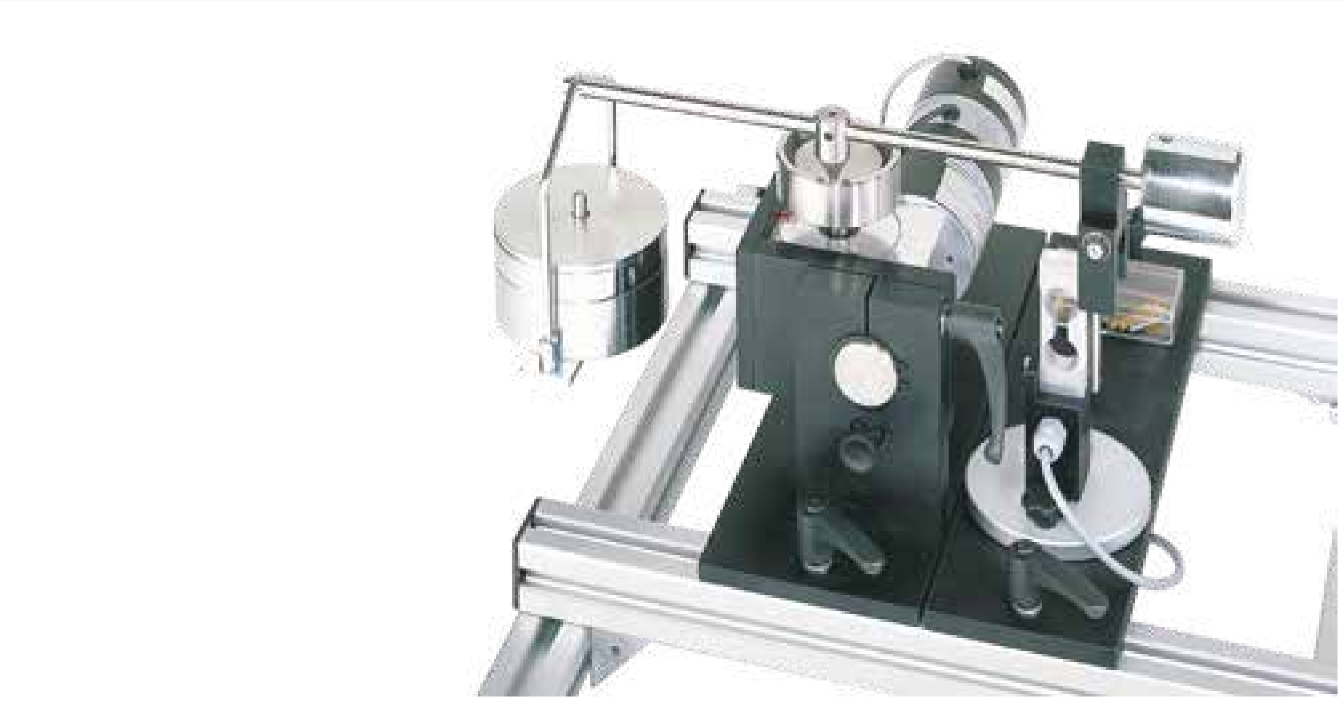
Force sensor: 0...50N

LxWxH: 350x250x550mm
Weight: approx. 8kg

Scope of delivery

1 experimental unit
1 sphere
1 glass plate
1 set of instructional material

TM 260.03
Dynamic friction in pin - disk



Description

- **frictional forces between two sliding friction pairs**
- **investigation of wear**
- **use of different lubricants possible**

In bearing and drive technology, dynamic friction occurs at the sliding and rolling points, which leads to power losses in the technical systems. Dynamic friction is differentiated into sliding, rolling and spinning friction. In dynamic friction, there is relative translation between the two bodies.

The tribological system in TM 260.03 allows a clear representation of the dynamic friction and an analysis of the frictional forces. The experimental unit contains a fixed pin that is pressed axially against a rotating disk as the friction pair. The contact force between the friction partners can be adjusted gradually up to a maximum of 80 N by means of a lever. The rotating disk is enclosed by an open cup that can be filled with different lubricants for the experiments.

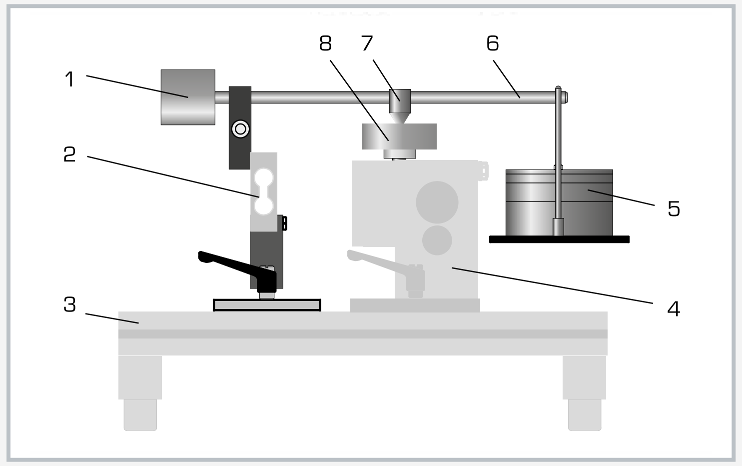
Different lubrication conditions can be studied, such as dry friction, water or oil lubrication. Pins made of different materials are included in the scope of delivery to study different friction pairings.

The TM 260 drive unit is required in order to conduct experiments. The experimental unit is mounted quickly and easily on the frame of the drive unit with quick-action chucks. The disk is driven by a clampable coupling between drive unit and gear unit. The display and control unit of the drive unit shows frictional force and speed and allows the continuous adjustment of the speed.

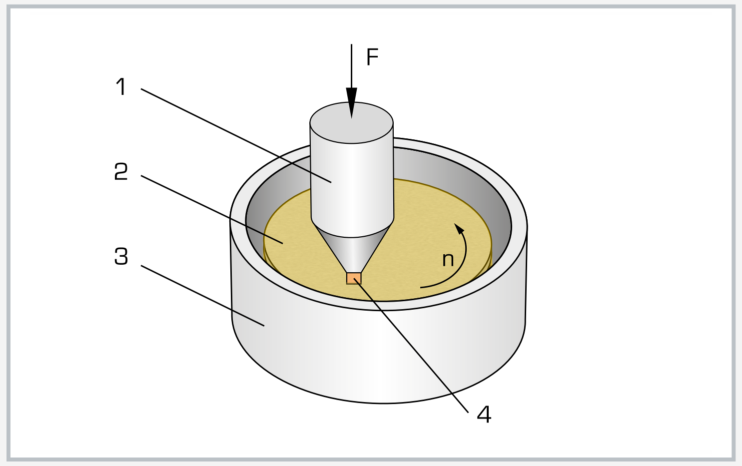
The frictional force and the coefficient of friction can be determined in experiments. The frictional forces are measured by a force sensor. The wear can be determined precisely by measuring the change (reduction) in length of the pin.

Learning objectives/experiments

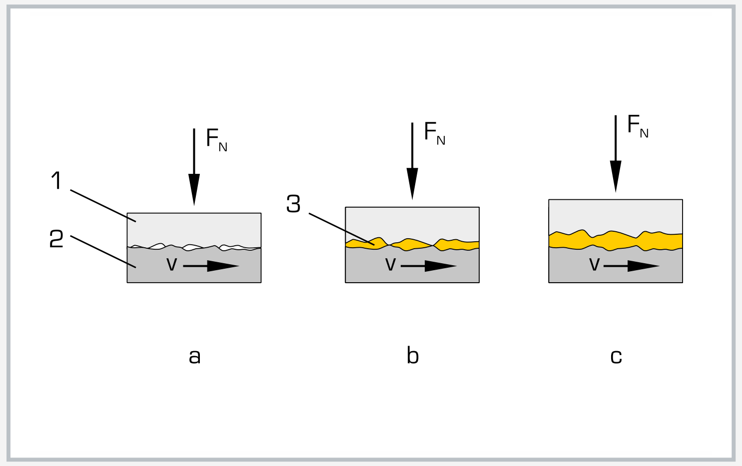
- together with the drive unit
  - frictional forces in different friction pairs and loads
  - frictional forces with different lubrication
  - frictional forces at different relative speeds of the friction partners
  - wear under different friction parameters and lubrication conditions



1 counterweight, 2 force sensor, 3 frame of TM 260, 4 drive unit from TM 260, 5 weight, 6 load application device lever, 7 pin, 8 disk



Tribological system pin and disk: 1 pin as counter body, 2 rotating disk as main body, 3 cup with lubricant as intermediate substance, 4 contact area; F force, n speed



Effect of the lubricating film on friction: 1 pin, 2 disk, 3 lubricant; a dry friction, b mixed friction, c fluid friction; F_N force, v velocity

Specification

[1] frictional forces in pin and disk, which slide against each other, disk subjected to axial load
[2] quick and easy assembly of the experimental unit on the frame of the drive unit
[3] disk is driven by a clampable coupling between drive unit and gear unit
[4] fixed pin made of different materials: aluminium, brass or steel
[5] rotating disk made of hardened and ground stainless steel
[6] load on the pin via lever arm and stepped weights
[7] use of different lubricants, e.g. water or oil
[8] frictional force measured by force sensor
[9] displays of force and speed and speed adjustment on the drive unit

Technical data

Load application device
- max. load: 80N
- lever arm ratio: 2:1

Disk
- Ø=50mm
- hardened stainless steel, ground

Pin, ØxH: 4x25mm
- 3x aluminium
- 6x brass
- 6x steel

Force sensor for frictional force
- 0...50N

Weights
- 1x 5N (hanger)
- 1x 20N
- 1x 10N
- 1x 5N

LxWxH: 350x430x230mm
Weight: approx. 8kg

Scope of delivery

1 experimental unit
1 disk
1 set of pins
1 set of weights
1 set of instructional material

TM 260.04
Frictional vibrations

Description

- **slip–stick phenomenon at the transition from static to dynamic friction**
- **friction rings of different materials for the study of different friction pairings**

Friction is the resistance of a body against movement on a base. Static friction means that a body remains at rest under the action of a force. If a limit value is exceeded, the body begins to move on the base, resulting in dynamic friction. Self-excited friction oscillations, also known as slip–stick phenomenon, occur if the static friction is significantly higher than the dynamic friction.

The tribological system in TM 260.04 allows a clear demonstration of the transition from static to dynamic friction and the occurrence of friction oscillations. The experimental unit contains a rotating stainless-steel disk and a loosely fitting friction ring as the friction pair. The contact force between the friction partners can be adjusted gradually up to a maximum of 40 N by means of weights.

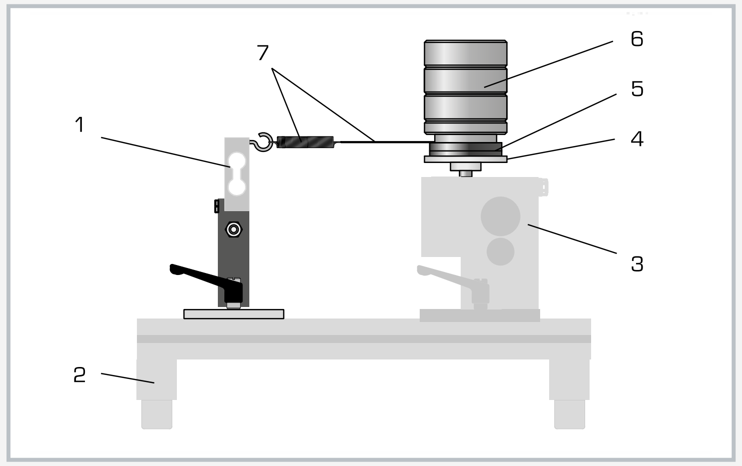
A tension spring prevents the friction ring from rotating. The necessary holding force is measured by a force sensor.

The TM 260 drive unit is required in order to conduct experiments. The experimental unit is mounted quickly and easily on the frame of the drive unit with quick-action chucks. The disk is driven by a clampable coupling between drive unit and gear unit. The display and control unit of the drive unit shows frictional force and speed and allows the continuous adjustment of the speed.

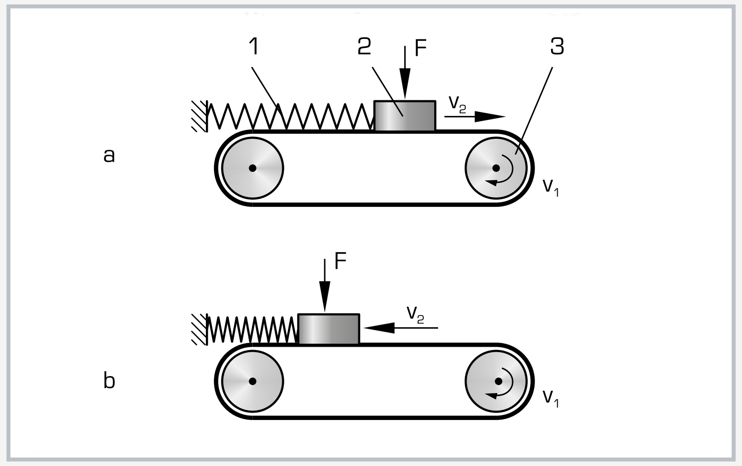
The frictional force and the coefficient of friction can be determined in experiments. The frictional forces are measured by a force sensor. Friction rings made of different materials are included in the scope of delivery to study different friction pairings.

Learning objectives/experiments

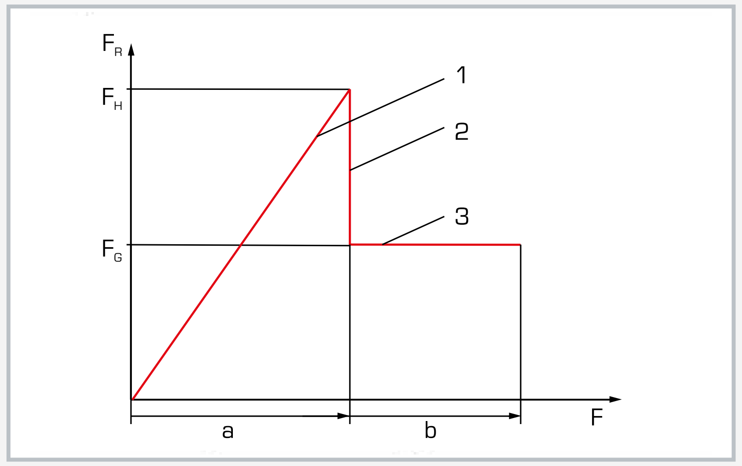
- together with the drive unit
  - observation of the transition from static to dynamic friction
  - influence of lubrication on slip–stick phenomenon
  - influence of the force between the friction partners on the slip–stick phenomenon
  - influence of the relative velocity of the friction partners on the slip–stick phenomenon



1 force sensor, 2 frame of TM 260, 3 drive unit from TM 260, 4 rotating disk, 5 friction ring, 6 weight, 7 spring and cable



Friction oscillations (Slip-stick phenomenon): 1 spring, 2 body, 3 drive; F force, v velocity, a static, b dynamic



Frictional force at static and dynamic friction: 1 static friction, 2 slide limit, 3 dynamic friction, F_R frictional force, F traction, F_H static frictional force, F_G dynamic frictional force, a rest state, b motion

Specification

[1] friction oscillations at static and dynamic friction
[2] quick and easy assembly of the experimental unit on the frame of the drive unit
[3] rotating stainless steel disk
[4] disk is driven by a clampable coupling between drive unit and gear unit
[5] friction ring of different materials: stainless steel, brass or plastic (PA)
[6] friction pair subject to load by stepped weights
[7] frictional force measured by force sensor
[8] displays of force and speed and speed adjustment on the drive unit

Technical data

Disk
- Ø: 60mm
- stainless steel

Friction ring
- outer diameter: 80mm
- inner diameter: 50mm
- 1x stainless steel
- 1x brass
- 1x plastic (PA)

Force sensor for frictional force
- 0...50N

Weights
- 1x 5N
- 3x 10N

Weight: approx. 7kg

Scope of delivery

1 experimental unit
1 disk
1 friction ring
1 spring
1 set of weights
1 set of instructional material

TM 260.05

Dynamic friction in cylindrical pin - roller

Description

- **frictional forces between two sliding friction pairs**
- **investigation of wear**
- **use of different lubricants possible**

In bearing and drive technology, dynamic friction occurs at the sliding and rolling points, which leads to power losses in the technical systems. Dynamic friction is differentiated into sliding, rolling and spinning friction. In dynamic friction, there is relative translation between the two bodies.

The tribological system in TM 260.05 allows a clear representation of the dynamic friction and an analysis of the frictional forces. The experimental unit contains a fixed cylindrical pin that is pressed radially against a rotating roller as the friction pair. There is point contact between the friction partners. The contact force between the friction partners can be adjusted gradually up to a maximum of 80 N by means of a lever. The experimental unit includes a tank that supplies lubricant.

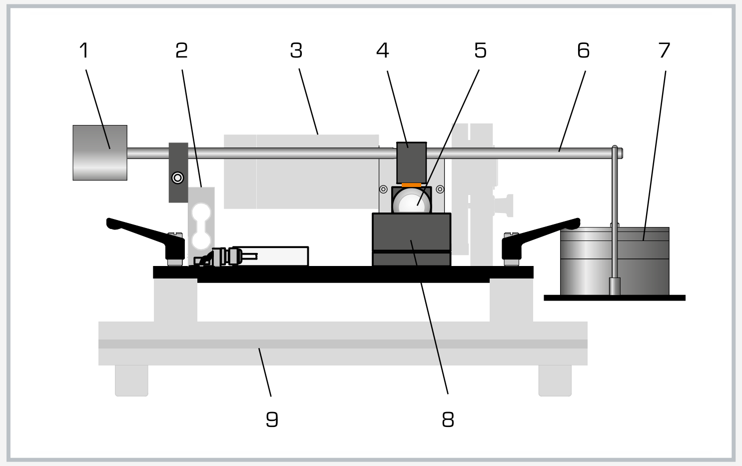
Different lubrication conditions can be studied, such as dry friction, water or oil lubrication. Cylindrical pins made of different materials are included in the scope of delivery to study different friction pairings.

The TM 260 drive unit is required in order to conduct experiments. The experimental unit is mounted quickly and easily on the frame of the drive unit with quick-action chucks. The roller is driven by a clampable coupling between drive unit and gear unit. The display and control unit of the drive unit shows frictional force and speed and allows the continuous adjustment of the speed.

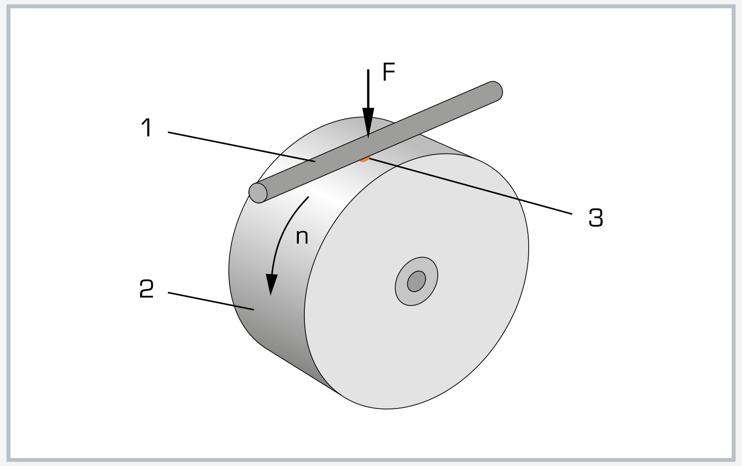
The frictional force and the coefficient of friction can be determined in experiments. The frictional forces are measured by a force sensor.

Learning objectives/experiments

- together with the drive unit
  - frictional forces in different friction pairs and loads
  - frictional forces with different lubrication
  - frictional forces at different relative speeds of the friction partners
  - wear under different friction parameters



1 counterweight, 2 force sensor, 3 drive unit from TM 260, 4 sliding holder with cylindrical pin, 5 roller, 6 load application device lever, 7 weight, 8 tank for lubricant, 9 frame from base module TM 260



Tribological system of cylindrical pin and roller (point contact): 1 fixed cylindrical pin as counter body, 2 rotating roller as main body, 3 lubricant as intermediate substance; F force, n speed

Specification

[1] frictional forces in cylindrical pin and roller that slide on each other (point contact)
[2] quick and easy assembly of the experimental unit on the frame of the drive unit
[3] rotating roller made of hardened and ground stainless steel
[4] roller is driven by a clampable coupling between drive unit and gear unit
[5] fixed cylindrical pin made of different materials: aluminium, brass or steel
[6] load on the cylindrical pin via lever arm and stepped weights
[7] use of different lubricants, e.g. oil or water
[8] frictional force measured by force sensor
[9] displays of force and speed and speed adjustment on the drive unit

Technical data

Load application device
- max. load: 80N
- lever arm ratio: 2:1

Roller
- Ø=40mm
- hardened stainless steel, ground

Cylindrical pin, ØxH: 10x20mm
- 3x aluminium
- 6x brass
- 6x steel

Force sensor for frictional force
- 0...50N

Weights
- 1x 5N (hanger)
- 1x 20N
- 1x 10N
- 1x 5N

LxWxH: 570x100x120mm
Weight: approx. 8kg

Scope of delivery

1 experimental unit
1 roller
1 set of cylindrical pins
1 set of weights
1 set of instructional material

TM 260.06

Pressure distribution in journal bearings

Learning objectives/experiments

- together with the drive unit
  - pressure distribution in the journal bearing depending on speed
  - pressure distribution in the journal bearing depending on load or bearing gap width
  - stability limit as a function of the gap width

Description

- **depiction of radial pressure distribution in a journal bearing at different bearing gap widths**
- **bearing housing made of transparent plastic**

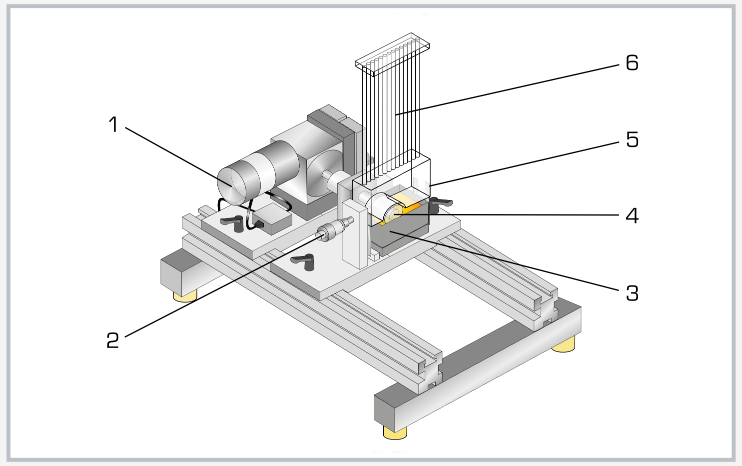
The field of tribology covers all forms of friction. Dry, mixed and fluid friction all occur in journal bearings. Under operating conditions there is completely distinct fluid friction, so that the shaft and bearing shell are separated by a supporting lubricating film. The supporting function of the lubricating film can be described by the pressure distribution in the bearing gap.

The experimental unit TM 260.06 is used to visualise the radial pressure profile in the journal bearing with hydrodynamic lubrication.

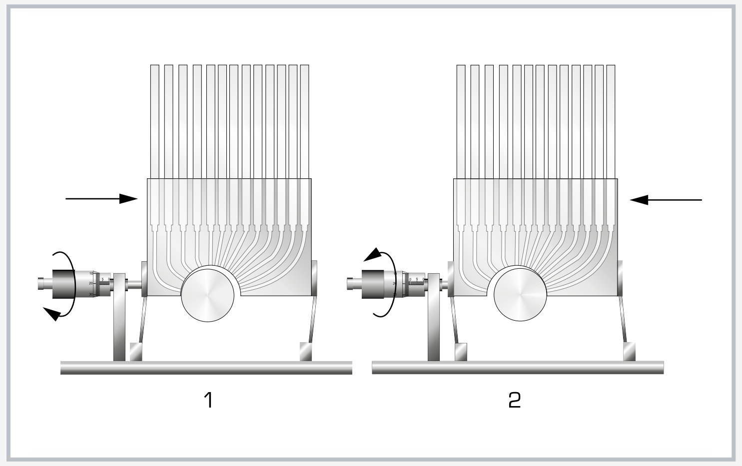
To this end, the experimental unit contains an open bearing shell which only encloses a shaft half way and which simulates the journal bearing. The bearing shell is secured to two spring plates in such a way that it can be moved. Unlike real hydrodynamic journal bearings, the gap width can be adjusted via the radially moveable bearing housing by means of the spring plates and a micrometer screw.

The TM 260 drive unit is required in order to conduct experiments. The experimental unit is quickly and easily mounted on the frame of the drive unit with quick-action chucks. The shaft is driven by a clampable coupling between drive unit and gear unit. The display and control unit of the drive unit shows frictional force and speed and allows the continuous adjustment of the speed.

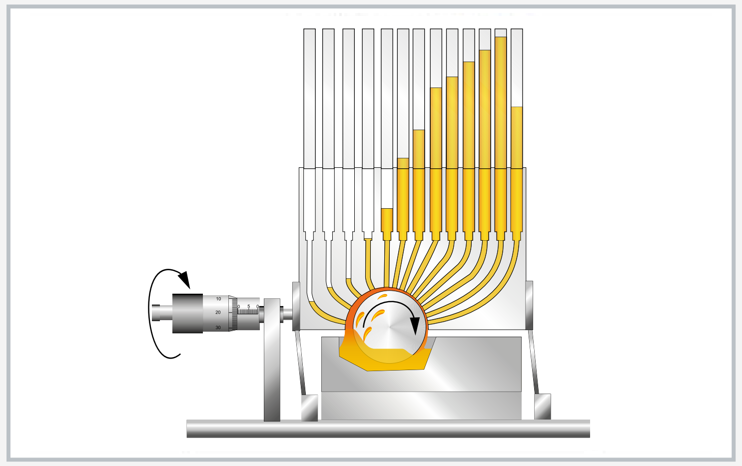
There are 13 measuring points around the circumference of the bearing shell to measure the pressure. The pressures are read off from a 13 tube manometers using the height of each column of liquid. The lubricant is supplied via an oil pan. The bearing shell is transparent, allowing close observation of the experiment.



1 TM 260 base module, 2 bearing gap width adjustment, 3 oil pan, 4 shaft, 5 bearing housing with bearing shell, 6 tube manometers



How adjustment of the bearing shell (bearing gap width) works: 1 bearing shell in right-hand position, 2 bearing shell in left-hand position



Pressure distribution over the bearing shell; pressure increases as the bearing gap decreases

Specification

[1] demonstration and visualisation of the pressure distribution in a journal bearing with hydrodynamic lubrication
[2] quick and easy assembly of the experimental unit on the frame of the drive unit
[3] roller is driven by a clampable coupling between drive unit and gear unit
[4] bearing housing is completely transparent
[5] moveable bearing housing, adjustable bearing gap
[6] 13 radial pressure measuring points on the bearing shell
[7] radial pressure distribution indicated with 13 tube manometers
[8] TM 260 base module required for operation

Technical data

Shaft
- diameter: 50mm
- length: 50mm
- material: stainless steel

Bearing shell
- diameter: 52,5mm
- bearing gap adjustable from: 0...2,5mm

Adjustment mechanism for bearing shell
- graduation: 0,01mm

Oil
- ISO viscosity grade: VG 32

Measuring ranges
- pressure: 360mm oil column
- speed: 0...200min^{-1}

LxWxH: 350x150x450mm
Weight: approx. 4kg

Scope of delivery

1 experimental unit
1 oil (0,5L)
1 set of instructional material

TM 232
Bearing friction

Learning objectives/experiments

- determine the frictional moment in slide bearings with various friction pairs
- determine the frictional moment of a rolling bearing
- comparison of slide and rolling bearings
- basic experiments on rotational dynamics

Description

- **friction in slide bearings and roller bearings**
- **interchangeable bearing shells for slide bearings of different materials**

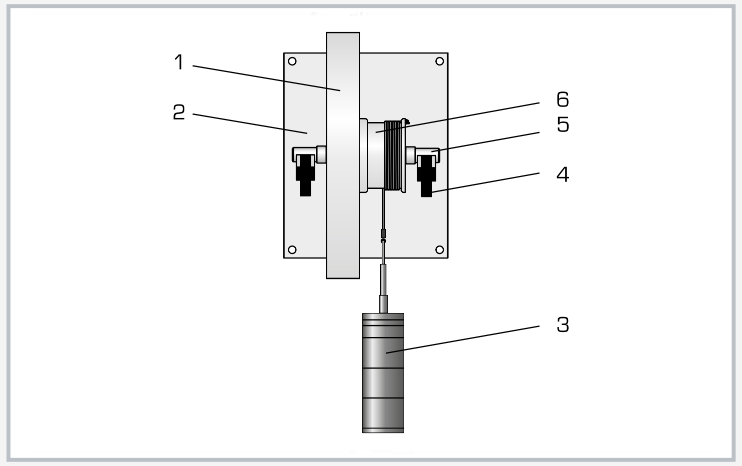
Bearings can be classified as slide bearings or roller bearings depending on the nature of their motion. In slide bearings, there is a sliding motion between the bearing and the supported component. In roller bearings, there is both sliding motion and rolling motion between rolling bodies and the supported component. Sliding motion is undesirable in roller bearings, e.g. between rolling body and cage. The bearing force is transferred in the roller bearing by means of rolling.

In both types of bearings—the slide bearing and the roller bearing—frictional forces occur during operation, which oppose resistance to the movement.

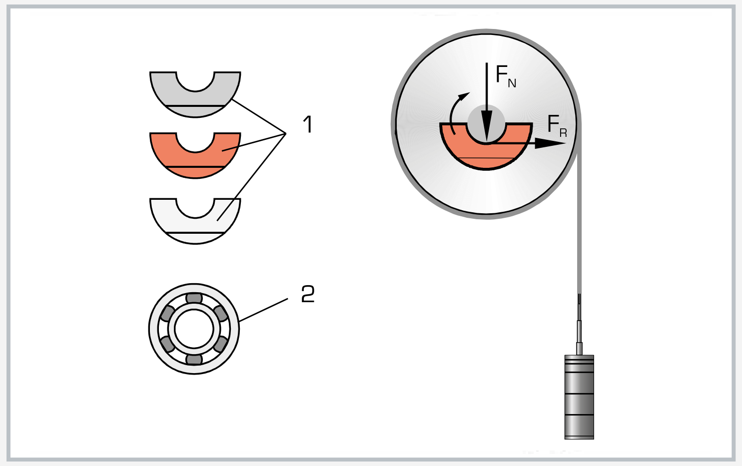
The TM 232 experimental unit allows investigations of friction on slide bearings with different bearing shells and on roller bearings. A shaft with a cable drum and flywheel is mounted on a base plate. The weight of the heavy flywheel generates bearing forces. A moment is applied by means of weights, which is equal to the friction moment at the start of the rotation. Replaceable bearing shells are used as slide bearings.

The coefficients of friction are determined in experiments. Bearing shells made of different materials are included in the scope of delivery in order to study different friction pairings. The bearing friction is very low when using the roller bearing. In this case, the flywheel can be used for basic experiments on rotational dynamics.

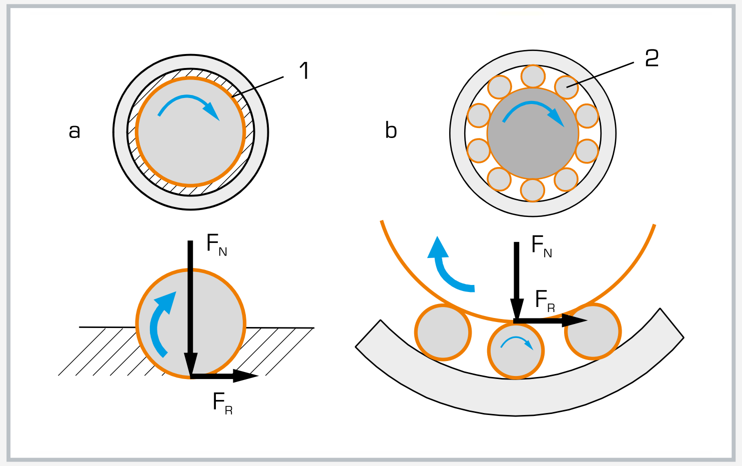
The experimental unit is designed to be fixed to a wall. The parts of the experiment are clearly laid out and securely housed in a storage system.



1 flywheel, 2 base plate, 3 weight, 4 bearing seat, 5 shaft, 6 cable drum



1 interchangeable bearing shells of cast iron, red bronze and plastic (PTFE), 2 roller bearing; F_N normal force, F_R frictional force



a dynamic friction in the slide bearing, 1 sliding surface
b dynamic friction and rolling friction in the rolling bearing, 2 roller bearing; F_N normal force, F_R frictional force

Specification

[1] comparison of dynamic friction and rolling friction
[2] experiments on rotational dynamics are possible
[3] bearing shells of different materials as slide bearings
[4] steel flywheel, galvanised
[5] drive via cable drum and weights
[6] storage system for parts
[7] bracket for wall mounting

Technical data

Bearing shells as slide bearing, half-shells
- GG-25
- red bronze
- PTFE (Teflon)

Deep-groove ball bearing
- type 6203

Shaft bearing journal
- Ø=17mm

Flywheel
- Ø=300mm
- weight: 22,2kg

Weights
- 1x 1N (hanger)
- 5x 1N
- 1x 2N
- 3x 5N

Base plate
- LxW: 250x200mm

LxWxH: 200x330x300mm
Weight: approx. 30kg
LxWxH: 290x140x130mm (storage system)

Scope of delivery

1 experimental unit
6 bearing shells
2 roller bearings
1 set of weights
1 storage system
1 set of instructional material

TM 282
Friction in journal bearings

Description

- **fundamentals of hydrodynamic lubrication**
- **friction states under different operating conditions**
- **electronic speed control and digital display of speed and lubricant temperature**

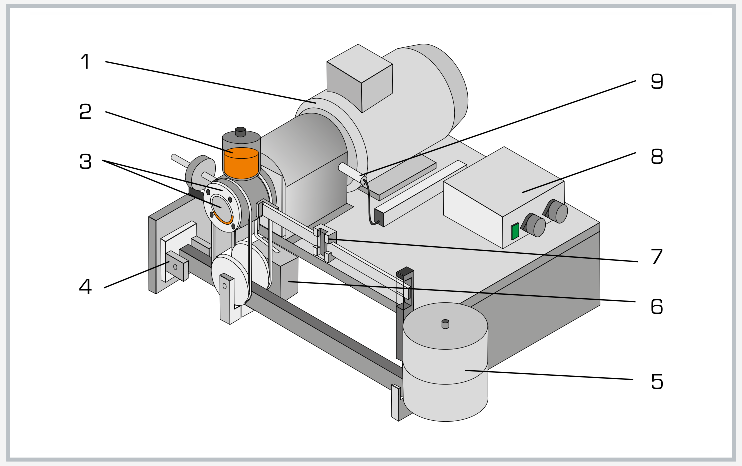
There a many factors that influence the friction states in a hydrodynamic journal bearing. Speed, load and viscosity of the lubricant used are focused on in particular.

TM 282 allows the study of various factors that influence friction. The journal bearing comprises an electrically driven shaft journal that rotates in a freely movable bearing housing. The movement of the oil in the bearing can be observed.

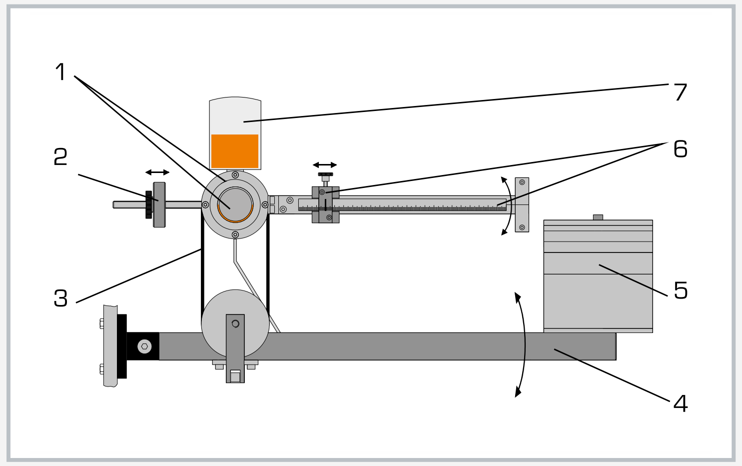
The applied load is transmitted to the bearing housing through a load application device and can be varied by means of weights. The frictional moment is determined by means of a movable weight that balances the moment on a balance beam. The journal is driven by an electric motor at a speed that can be adjusted by a frequency converter. The temperature (and therefore the viscosity) of the lubricant is recorded by a temperature sensor in the bearing shell and shown on a screen on the display and control unit. The lubricant is supplied via a wick oiler that applies the oil via two grooves in the bearing bush. The accumulated leakage oil is collected in a collecting tank.

Learning objectives/experiments

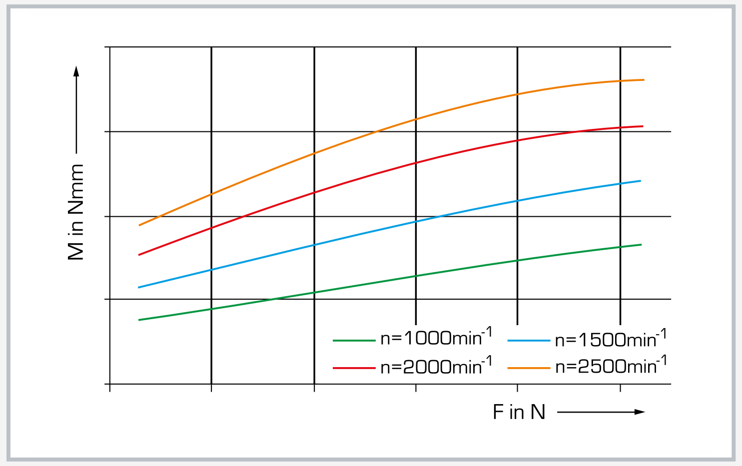
- develop an understanding of technological relationships of hydrodynamic lubrication by experimentation
- frictional moment in a journal bearing as a function of
  - speed
  - bearing load
  - lubricant and lubricant temperature



1 motor, 2 drip oiler, 3 journal bearing housing with shaft journal, 4 fixed support for loading lever, 5 weights, 6 tank for leak oil, 7 sliding weight to measure frictional moment, 8 switch box, 9 speed sensor



1 journal bearing housing with shaft journal, 2 tare weight, 3 belt to transfer force to the bearing housing, 4 loading lever, 5 weights, 6 measuring lever with scale and sliding weight, 7 drip oiler



Influence of the loading force F and the speed n on the frictional moment M

Specification

[1] investigation and visualisation of hydrodynamic bearing
[2] radial journal bearing with stainless steel journal and freely movable bronze bearing shell
[3] drip lubrication for continuous supply of lubricant (drip oiler)
[4] journal bearing subjected to load by means of mechanical lever
[5] variable speed via frequency converter
[6] frictional moment measured by level with sliding weight
[7] inductive speed measurement
[8] thermocouple in the bearing housing to measure the oil temperature
[9] display and control unit with digital displays for oil temperature and speed

Technical data

Journal bearing
- shaft diameter: Ø=30mm
- bearing width: 45mm
- friction pair: steel/bronze

Motor: 0,37kW
Oil viscosity grade: ISO VG 32

Weights
- 1x 50N, 1x 20N, 2x 10N, 2x 5N, 2x 5N
- lever transmission ratio: 5:1

Measuring ranges
- temperature: -50...200°C
- speed: 100...3000min^{-1}
- bearing load: max. 525N
- friction moment: max. 295Nmm

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase; 120V, 60Hz, 1 phase
UL/CSA optional
LxWxH: 610x440x360mm (experimental unit)
LxWxH: 360x340x160mm (display and control unit)
Weight: approx. 40kg

Scope of delivery

1 experimental unit
1 display and control unit
1 set of weights
1 oil (0,5L)
1 set of instructional material

TM 280
Pressure distribution in journal bearings

Learning objectives/experiments

- visualisation and investigation of instability in journal bearings
- displacement of the shaft journal as a function of the speed
- pressure distribution in the bearing under constant load and different speeds
- critical speed as a function of the load
- critical speed as a function of the oil temperature

Description

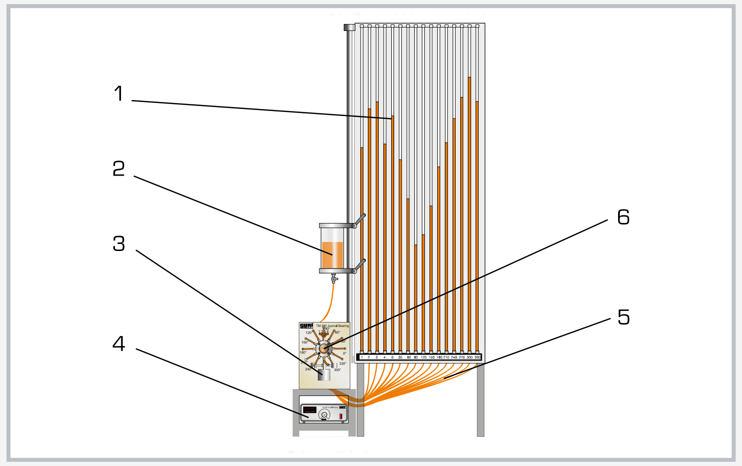
- **ideal observation of the function thanks to transparent bearing housing**
- **clear representation of the pressure distribution in the journal bearing**
- **investigation and visualisation of instability in journal bearings**

In hydrodynamic journal bearings, the shaft and the bearing shell are separated from each other by a lubricating film during operation. The supporting function of the lubricating film in a journal bearing can be described by the pressure distribution in the bearing gap.

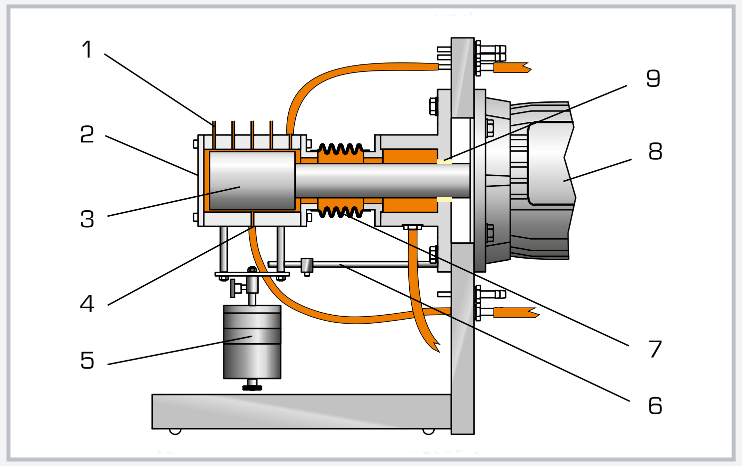
The TM 280 unit is used to visualise the pressure curve in the journal bearing with hydrodynamic lubrication. To do this, there are twelve measuring points around the circumference of the bearing shell and four measuring points in the longitudinal direction. The respective pressures can be read via a 16 tube manometers with reference to the height of the liquid columns.

The journal bearing comprises an electrically driven shaft journal that rotates in a freely movable bearing housing. Oil is used as the lubricant.

The displacement of the shaft journal depends on the speed and direction of rotation as well as the characteristic behaviour during start-up, and can be observed through the transparent bearing housing. Speed and direction can be adjusted. The load on the journal bearing can be adjusted by varying the weights. The temperature in the bearing gap is measured in order to determine the viscosity of the lubricant.



1 tube manometers, 2 tank for oil, 3 weight, 4 display and control unit for speed control, 5 measuring hoses, 6 journal bearing with drive



1 measuring points, 2 transparent bearing housing, 3 journal, 4 measuring point, 5 weight, 6 anti-twist device, 7 bellows, 8 drive motor, 9 radial sealing ring

Detailed view of the TM 280 journal bearing unit

Specification

[1] visualisation and investigation of pressure distribution in journal bearings
[2] bearing housing is completely transparent
[3] continuously adjustable speed, electronically controlled
[4] bearing subjected to load by means of weights
[5] temperature measurement in the bearing housing
[6] 12 measuring points on the periphery, 4 measuring points in the longitudinal direction
[7] pressure distribution indicated with 16 tube manometers
[8] digital display of speed on the display and control unit

Technical data

Bearing
- nominal bearing diameter: 51mm
- bearing gap width: 4mm
- bearing width: 75mm
- bearing load: 6,7...16,7N

Motor
- power: 0,37kW
- max. speed: 3000min^{-1}

Oil ISO viscosity grade: VG 32

Tank for oil: 2,5L

Weights
- 1x 1N (hanger)
- 2x 2N
- 1x 5N

Measuring ranges
- pressure: 1770mm oil column, 16x
- temperature: -10...50°C
- speed: 0...3000min^{-1}

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase; 120V, 60Hz, 1 phase
UL/CSA optional
LxWxH: 1100x750x2650mm
Weight: approx. 110kg

Scope of delivery

1 trainer
1 display and control unit
1 set of tools
1 set of weights
1 hydraulic oil (5L)
1 handheld temperature measuring unit
1 set of instructional material

TM 290

Journal bearing with hydrodynamic lubrication

Learning objectives/experiments

- determine the coefficients of friction at various loads and speeds, compare with Stribeck curves
- influence of speed, bearing clearance and bearing load on the displacement of the shaft
- influence of speed, bearing clearance, bearing load and lubricant on the frictional moment
- locus of the shaft

Description

- **frictional moment under different bearing clearances and loads**
- **pressure distribution in the journal bearing**
- **locus of the shaft under different loads and speeds**

In hydrodynamic bearings, the shaft and the bearing shell are separated from each other during operation by a supporting lubricating film. The pressure in the lubricating film in hydrodynamic journal bearings is generated by the relative motion between bearing shell and shaft. The position of the shaft in relation to the speed and the load is important for an analysis of the tribological process in the bearing shell of a journal bearing.

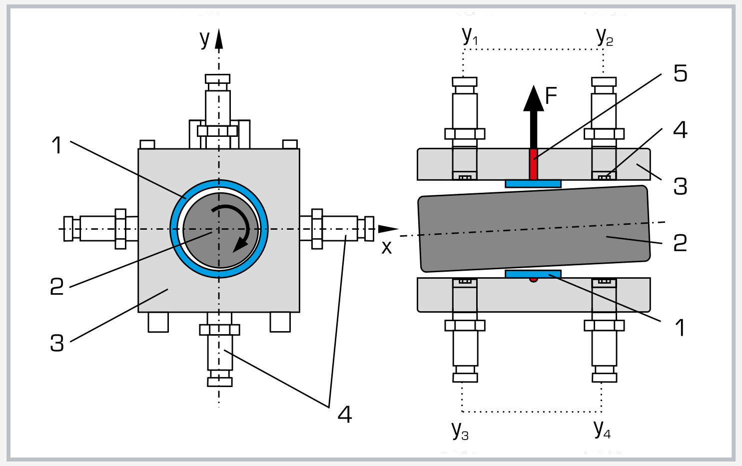
The TM 290 trainer allows the study of a hydrodynamically lubricated radial journal bearing. Five shafts with different diameters allow the operating behaviour to be analysed as a function of the bearing clearance.

The radial load on the journal bearing is applied by means of a handwheel and measured electronically. Similarly, the frictional moment is measured using a force sensor. The shaft is driven by a three-phase motor. The speed is continuously adjustable via a frequency converter and is displayed digitally. The oil temperature is adjusted using a controller.

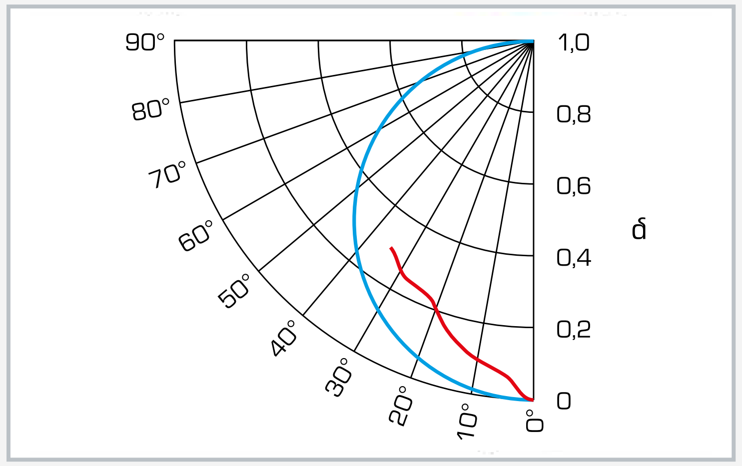
Inductive sensors detect the relative motion of the shaft in the bearing. This measurement makes it possible to plot a locus of the shaft as a function of load and speed. The position is measured, averaged and displayed at four points on the shaft in each of the X and Y directions.

Oil temperature, oil pressure and oil peak pressure in the bearing are measured and displayed by additional sensors. The measured values are read from digital displays and can be transmitted simultaneously via USB directly to a PC where they can be analysed using the software included.

1 handwheel for load, 2 force sensor for frictional moment, 3 inductive displacement sensors, 4 shaft, 5 bearing housing, 6 displays and controls



Sectional views of the journal bearing: 1 bearing shell, 2 shaft, 3 bearing housing, 4 displacement sensors (4 in X direction, 4 in Y direction), 5 oil supply; F load



Movement of the shaft centre point during operation or startup behaviour, blue: theoretical semicircle curve, red: measuring results of TM 290; δ relative lubricating film thickness

Specification

[1] friction states in hydrodynamically lubricated journal bearing
[2] 5 shafts with different diameters for experiments with different bearing clearances
[3] shaft driven by three-phase motor with frequency converter for continuous adjustment of the speed
[4] controller to adjust the oil temperature
[5] radial load of the bearing by means of compression spring and threaded spindle with handwheel and measured via force sensor
[6] determine the frictional moment by means of lever arm with force sensor
[7] 8 inductive displacement sensors for measuring the displacement of the shaft
[8] digital displays for radial load, frictional moment, position of the shaft (X and Y direction), oil pressure, peak oil pressure, oil temperature and speed
[9] GUNT software for data acquisition via USB under Windows 7, 8.1, 10

Technical data

Journal bearing
- rated diameter of the shaft: 50mm
- radial load: 0...1000N
- bearing clearance: 0,12mm; 0,14mm; 0,16mm; 0,18mm; 0,28mm

Drive motor with frequency converter
- power: 0,55kW
- speed: 0...1600min^{-1}

Hydraulic unit to adjust the oil temperature
- flow rate: 1,4L/min, pressure: 2bar
- tank capacity: 10L

Measuring ranges
- frictional moment: 0...1Nm
- radial load: 0...1000N
- displacement in X direction: ±1,000mm
- displacement in Y direction: ±1,000mm
- oil pressure supply: 1x 0...10bar
- oil pressure journal bearing: 1x 0...16bar
- oil temperature: 0...100°C
- speed: 0...1600min^{-1}

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase; 120V, 60Hz, 1 phase
UL/CSA optional
LxWxH: 1200x800x1450mm
Weight: approx. 225kg

Required for operation

PC with Windows recommended

Scope of delivery

1 trainer
1 set of tools
1 oil (5L)
1 GUNT software CD + USB cable
1 set of instructional material

CE 105
Corrosion of metals

Description

- **principles of corrosion and corrosion protection on metallic materials**
- **oxygen corrosion**
- **electrochemical corrosion (local elements)**
- **corrosion protection with external voltage and sacrificial anodes**

Corrosion damage to metallic components causes considerable economic and technical damages. The issue of corrosion and corrosion protection therefore plays an important role in technical training.

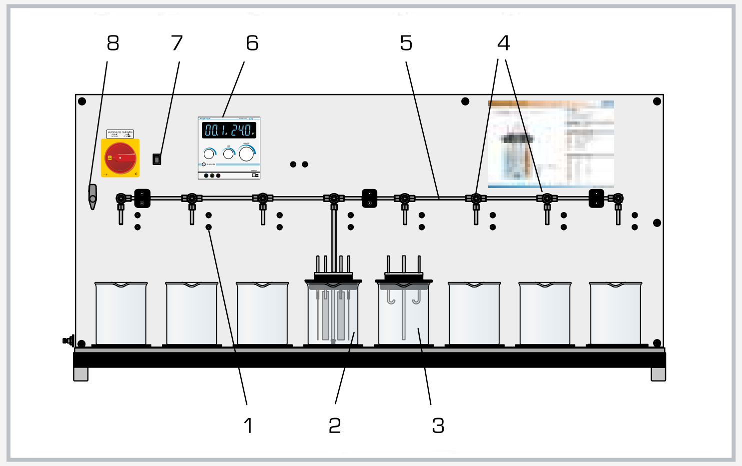
The CE 105 allows a variety of factors that influence corrosion processes to be investigated in parallel. Eight glass vessels are available to do this. They allow different materials to be compared under different conditions. The required electrolyte solution is added to the vessels. Up to six specimens can be attached to the cover of each vessel and these are immersed in the solution.

It is possible to connect specimens to an electrical conductor to investigate local elements and the principle of sacrificial anodes. An adjustable power pack allows an external voltage to be connected. This counters the current flow between precious and base metals in local elements. As result the corrosion rate of the more base metal is reduced.

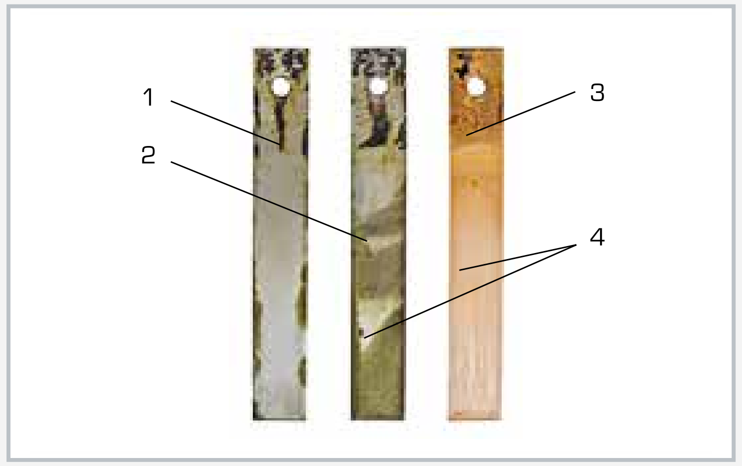
A diaphragm pump conveys ambient air into the electrolyte solution as required. Flow control valves can be used to individually adjust the gas flow rate for each vessel. It is also possible to feed other gases provided by the laboratory into the electrolyte solution. A pH meter is included to allow the influence of the electrolyte solution on corrosion processes to be investigated and compared.

Learning objectives/experiments

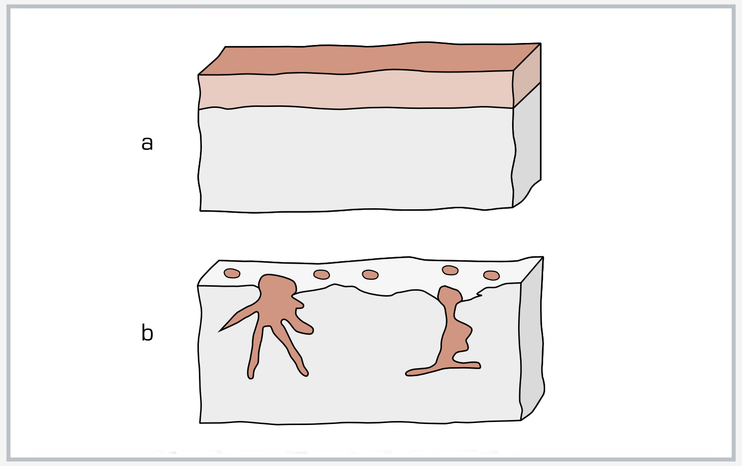
- corrosion behaviour of different metallic materials (rust / passivation)
- formation of local elements
- influence of pH value of the electrolyte solution
- influence of salt concentration in the electrolyte solution
- oxygen corrosion
- corrosion protection
  - external voltage
  - sacrificial anodes
  - protective layers



1 electrical connecting sockets, 2 electrolyte vessel with specimens and specimen holders (clamps), 3 electrolyte vessel with specimen holders (hooks), 4 flow control valves, 5 gas supply, 6 power pack, 7 diaphragm pump switch, 8 air / external gas supply reversing valve



Experimental result: a steel specimen (2) and a copper specimen (3) were electrically connected (4) and supplied with an external voltage. A steel specimen (1) with no electrical connection was used as a reference.



Two corrosion types: a surface corrosion, b pitting

Specification

[1] investigation of corrosion and corrosion protection measures
[2] 8 electrolyte vessels with covers and 6 specimen holders each
[3] adjustable power pack for application of external voltage
[4] air supply via diaphragm pump
[5] reversing valve for air or external gas supply
[6] adjustment of gas flow rate for each vessel using flow control valves
[7] recording of pH value of electrolyte solutions using manual unit
[8] pressure range for external gas supply: 0,2...1,0bar

Technical data

Electrolyte vessels
- capacity: 1000mL
- material: glass

Power pack
- voltage: 0...30VDC
- current: 0...5A

Diaphragm pump: approx. 260L/h

Specimens
- 6x stainless steel, steel, copper, brass, aluminium
- 3x glass
- dimensions: 100x15x1mm

Measuring ranges
- pH value: 0...14
  - resolution: 0,01

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase; 120V, 60Hz, 1 phase
UL/CSA optional
LxWxH: 1280x460x630mm (experimental unit)
Weight: approx. 55kg
LxWxH: 730x480x240mm (storage system)
Weight: approx. 15kg

Scope of delivery

1 experimental unit
1 pH meter
1 set of specimens
1 set of cables
1 coupling to connect an external gas supply
1 storage system
1 set of instructional material