Basic knowledge

MATERIALS TESTING

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 Stiffness, material behaviour under static load	Tensile test, compression test, bending test, torsion test
Creep behaviour	Creep rupture test
Toughness	Impact test
Fatigue behaviour, fatigue strength	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 fi ssured 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 honey-comb 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 infl uence of direct stress	Tensile test, impact test
Fatigue fracture • can develop following repeated stress under the infl uence 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.	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

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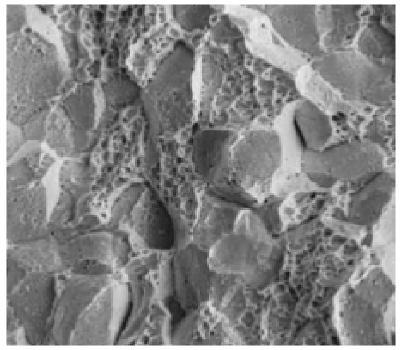
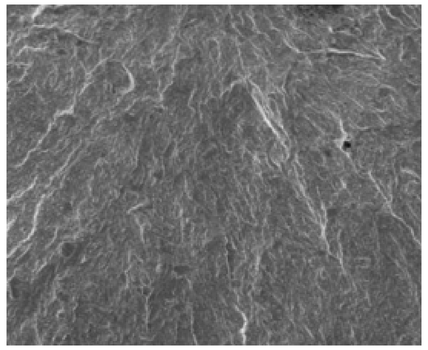
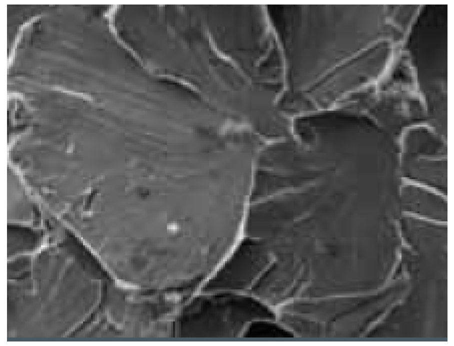
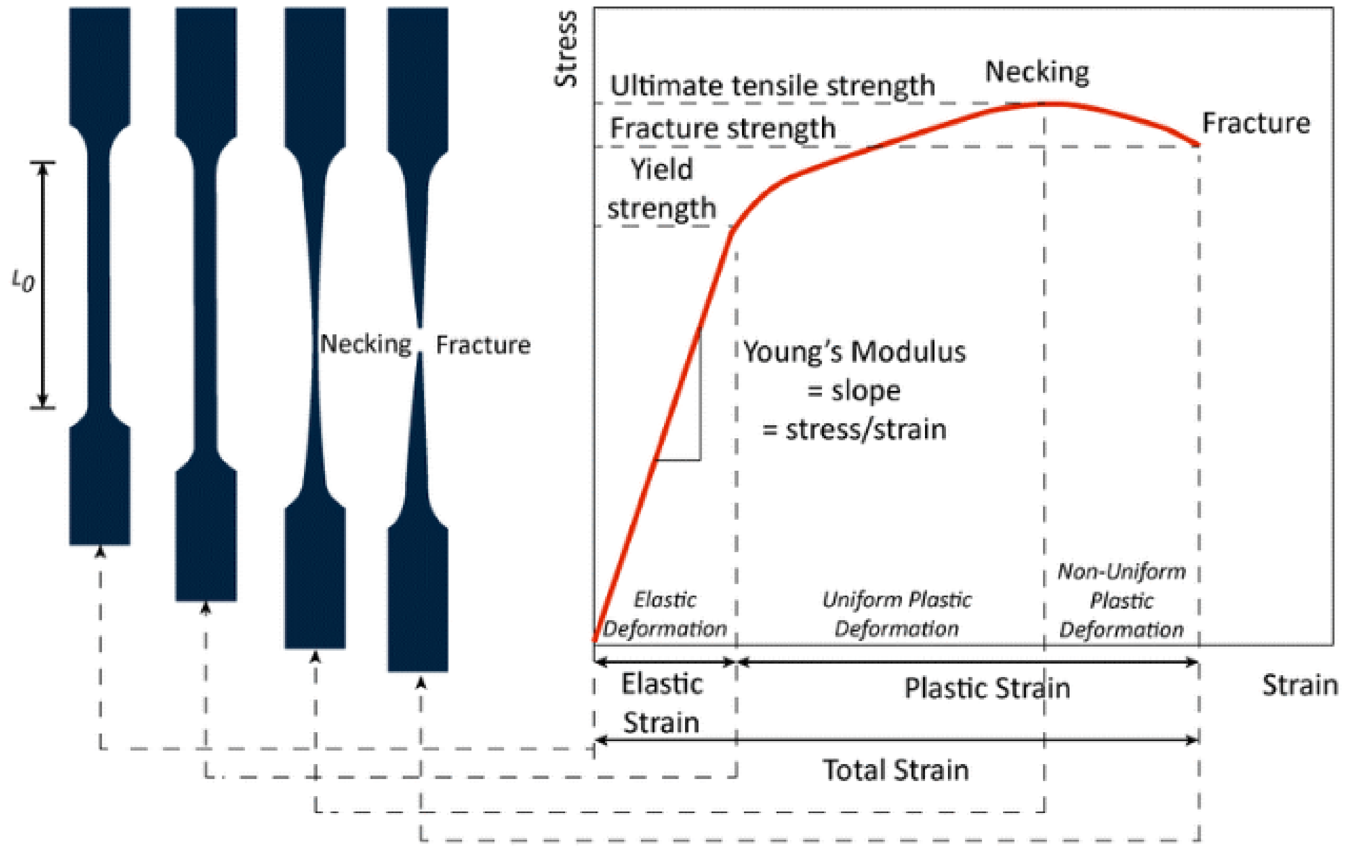
Honeycomb fracture	Fatigue fracture	Cleavage fracture
		

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 loadextension diagram.



Stress-strain diagram: the shape of the specimen changes during tensile testing

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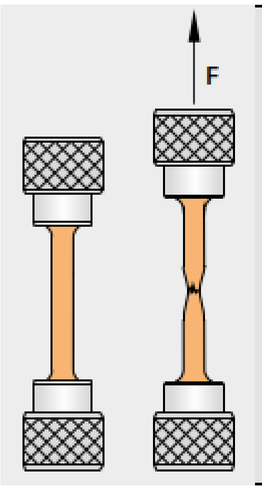
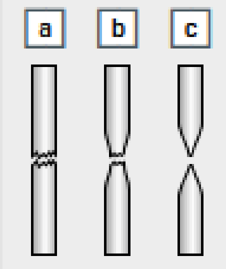
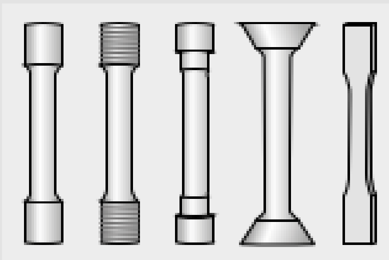


Selection of specimen forms for tensile tests according



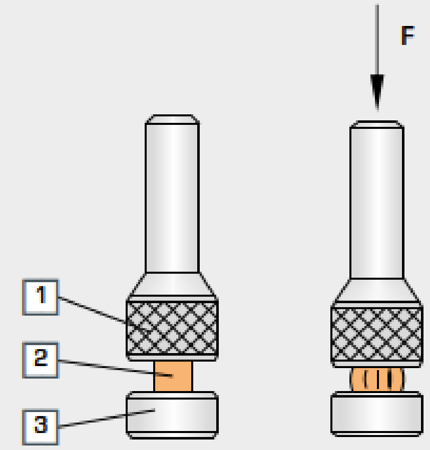


Test process of a classic tensile test
F force, **a** low-deformation fracture, **b** ductile fracture, **c** completely ductile fracture

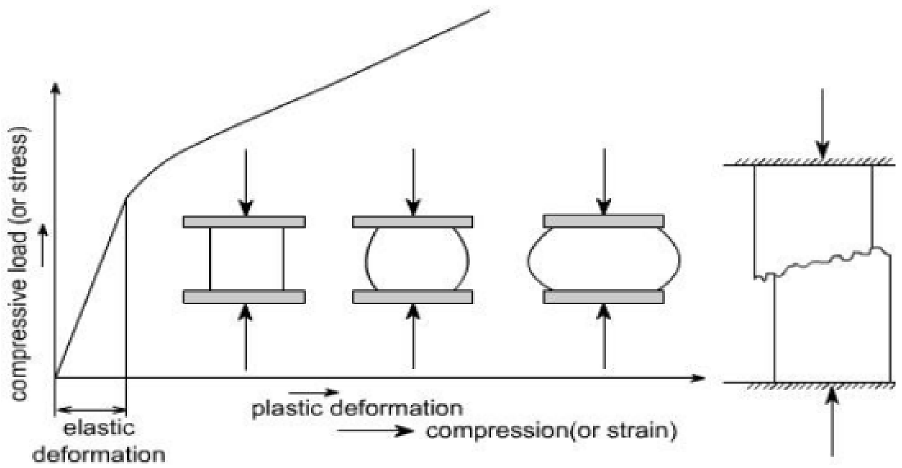
Compression test to determine flow curves

Compression tests are less signifi cant 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.

Brittle materials in compression typically have an initial linear region followed by a region in which the shortening increases at a higher rate than does the load. Thus, the compression stress – strain diagram has a shape that is similar to the shape of the tensile diagram.



Test process in the compression test
1 thrust plate, **2** specimen, **3** pressure plate, **F** test load



However, brittle materials usually reach much higher ultimate stresses in compression than in tension.

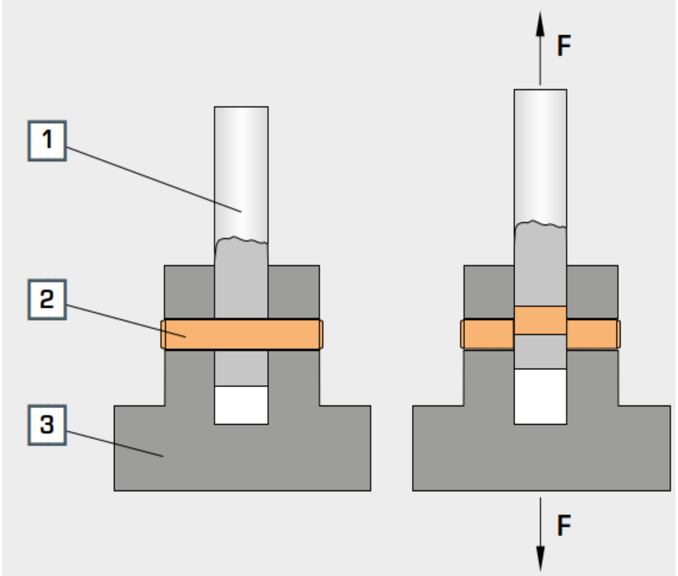
Brittle materials in compression behave elastically up to certain load, and then fail suddenly by splitting or by cracking in the way as shown in diagram.

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.

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

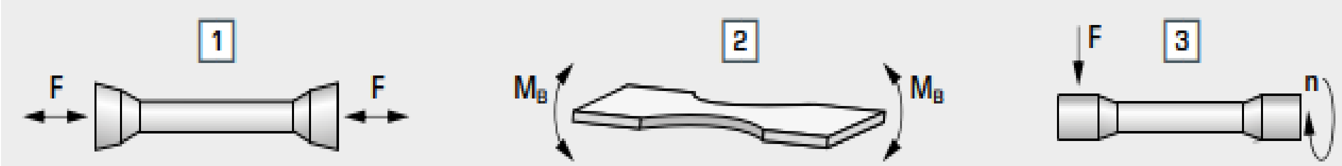
Shear strength in the double-shear method

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

Material fatigue. Fatigue strength test

The fatigue strength defi nes 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, **M_B** bending moment, **n** speed