Strength of materials

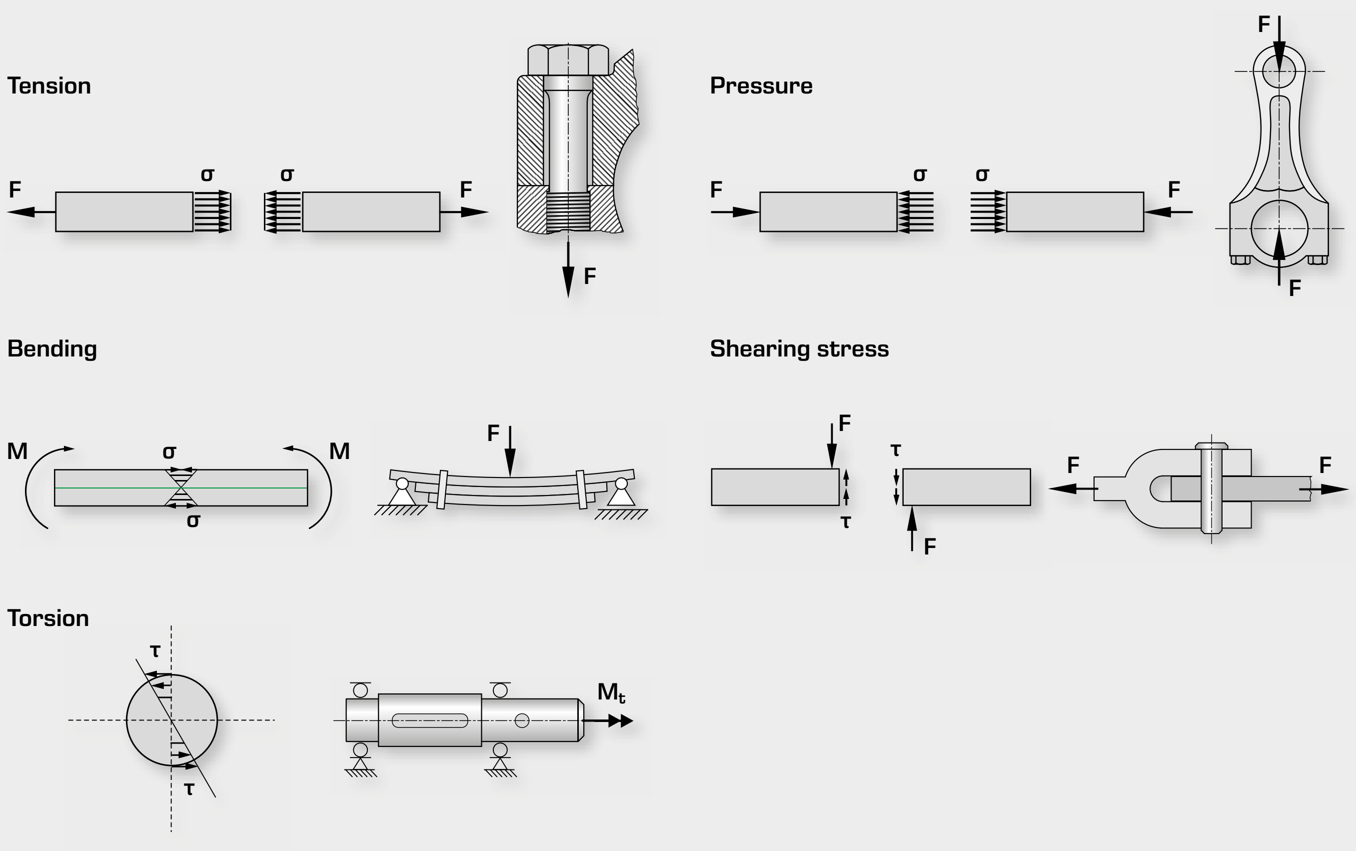
Strength of materials is based on statics. The idealisation of a real body as a rigid body in statics allows determining the external and internal forces on structures under equilibrium. Ensuring equilibrium is not sufficient for calculating the mechanical behaviour of components, including strength, rigidity, stability, fatigue strength and ductility, in the real world of engineering practice. Knowledge of the deformability of material bodies is required, without consideration of the material.

Strength of materials deals with the effect of forces on deformable bodies. In addition, material-dependent parameters should be considered as well. An introduction to the strength of materials is, therefore, given by the concept of stress and strain and by Hooke's law, which is applied to tension, pressure, torsion and bending problems.

Basic terms of materials strength

Types of stress

Components can be subjected to stress in different ways: tension, pressure, shear stress, bending, torsion, buckling and composite stresses.



F force, **M** moment, $\mathbf{M_t}$ twisting moment, **σ** stress, **τ** shear stress

Mechanical stress

When loads, moments, or forces externally act on a component, it internally creates force flows. The distribution of these loads is called mechanical stress. Mechanical stress is, therefore, defined as force per unit area. We distinguish two different cases:

Perpendicular force action on the section, direct stress **σ**	$\sigma = \frac{F}{A}$	Parallel force action to the section, shear stress **τ**	$\tau = \frac{F}{A}$

F force, **A** section, **σ** stress, **τ** shear stress

Elastic deformation, law of elasticity

Machines and components elastically deform under the action of forces. While the load is not large enough, purely elastic deformation remains. The law of elasticity describes the elastic deformation of solids when this deformation is proportional to the applied force.

Energy methods

Geometric considerations play a subordinate role in the energy methods. Instead of the previously used equilibrium conditions, we investigate how much work is produced by external forces during deformation of a system and in which energy form and where this work is stored.

In studying the strength of materials, the energy methods are based on the law of conservation of energy and on the principle that all energy transferred to a body or a system from outside is converted to internal energy, e.g. into deformation, change in velocity, or heat.

Different energy methods are used to calculate general systems and to investigate the stability of elastic structures, such as the principle of virtual displacement, the principle of virtual forces, the Maxwell-Betti theorem, or Castigliano's theorem.

The starting point of all energy methods is the **principle of virtual work.** It expresses an equilibrium condition and states: If a mechanical system is in equilibrium under the effect of external and internal forces, then the sum of the total virtual work, produced by internal and external forces and any virtual displacement are equal to zero.

Principle of virtual work

$$\delta W = F \cdot \delta x = 0; \quad \delta W = M \cdot \delta \varphi = 0$$

$$\delta W = \sum \delta W = \sum F \cdot \delta x = 0$$

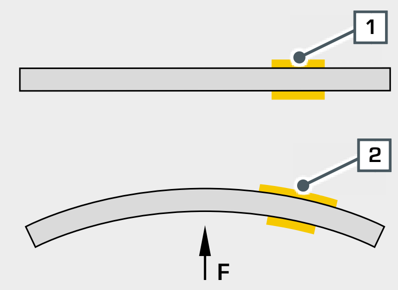
$$\delta W = \sum \delta W = \sum M \cdot \delta \varphi = 0$$

δW virtual work,
δx virtual displacement,
δφ virtual twisting angle,
M moment, **F** force

Experimental stress and strain analysis as proof of stresses

Strain gauge

Experimental stress and strain analysis uses the mechanical stress that occurs in components under load to determine the material stress. An experimental method for determining mechanical stress is based on the relation between stress and the deformation it causes. This deformation is known as strain and occurs on the surface of the components, which means that it can be measured. The principle of strain measurement is an important branch of experimental stress and strain analysis.



F force, **1** strain gauge in component not under load,
2 strain gauge in component under load

Photoelasticity (transmitted light polariscope)

Photoelasticity is an optical experimental method for determining the stress distribution in transparent, generally planar equivalent bodies. Photoelasticity provides a complete picture of the stress field. Areas of high stress concentration and the resulting strain as well as areas under less load can be clearly visualised.

Photoelasticity is a proven method for verifying analytically or numerically performed stress analyses (e.g.: FEM). It is used for both obtaining quantitative measurements and demonstrating complex stress states.