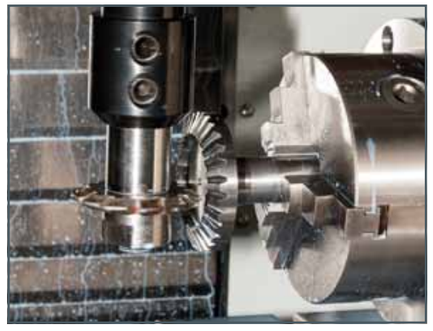
Basic knowledge

Kinematics and kinetics

Dynamics

While statics deals with bodies in equilibrium, i.e. which are at rest or moving with constant velocity, dynamics deals with the accelerated motion of a body caused by forces. As such, time plays a key role in dynamics. In dynamics, both the forces acting on a body and the resulting motions of the body are considered. Knowledge of dynamics is needed in all areas of mechanical engineering.



Dynamics comprises kinetics and kinematics. In practice, the difference between kinematics and kinetics is the way of looking at the same machine or component. Kinematic questions only consider the geometry of the motion. Kinetics also takes into account the cause of the motion.

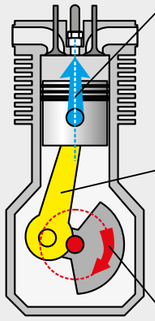
The aim of dynamics is to calculate the stress and strain on components or systems in order to be able to design them.

Kinematics

Kinematics describes and analyses the effect of motion on bodies, without taking into account the causes; it focuses on the geometric aspects of the motion. Coordinates describe the position of the body at any point in time. The path, velocity and acceleration are considered.

In practice, knowledge of kinematics is required for the construction and design of crank mechanisms, disk cams or gears. Only when the kinematics of a rigid body is fully understood, is it possible to apply motion equations that link forces on the body to motion.

In engineering, we distinguish between two forms of motion: translation and rotation. Most components of a machine undergo a combination of these two forms: general planar motion. This is illustrated by a simple piston engine:



Translation (parallel displacement):
the motion is rectilinear, but the body points do not necessarily move on straight trajectories. All body points undergo the same displacement.
Example: piston

General planar motion:
the body points undergo a combination of translation in a reference plane and rotation about an axis of rotation, which is perpendicular to the reference plane.
Example: connecting rod

Rotation:
all body points move on circular trajectories around the same spatially fixed axis of rotation.
Example: flywheel and shaft

Kinetics

Kinetics studies movements under the influence of forces; therefore, the cause of the motion is taken into consideration. To describe the spatial and temporal evolution of a mechanical system acted on by external forces, we use equations of motion. These generally comprise a system of second-order differential equations.

Kinetics are primarily based on **Newton's laws** of motion

1st law: principle or law of inertia

Without external force, a body remains at rest or in rectilinear uniform motion. Inertia: the body only changes its state of motion under the action of an external force.

2nd law: principle of action

The acting force and the acceleration achieved are proportional to each other. The ratio of the acting force to the acceleration achieved is constant for every body and equals its mass.

Fundamental law of dynamics:
force = mass · acceleration
$F = m \cdot a$

3rd law: principle of reaction or interaction

Reaction forces between two mass points are equal in magnitude, opposite in direction and collinear.

actio = reactio

Newton's fundamental law: $\sum F = m \cdot a$

Mass moment of inertia:

In translation, we refer to the inertia of a body; in rotation, this inertia corresponds to the mass moment of inertia.

If the rotational motion of a rigid body about a given axis is changed, the body resists the change. This resistance is given by the mass moment of inertia. Here, the behaviour of the body depends on its mass and its distribution relative to the axis of rotation. Both the mass and its distribution must be known to calculate the mass moment of inertia.

$$J = \frac{M}{\alpha}$$

$$J = r^2 \Delta m$$

J mass moment of inertia, **M** turning moment, **F** force,
α angular acceleration, **r** radius, **Δm** circumferential mass point

This behaviour is illustrated using the example of a tractor's flywheel mass; with regard to its axis of rotation, the flywheel mass has a large mass moment of inertia. If the flywheel mass has been set in motion, a large force must be applied to stop it. Consequently, the engine only delivers a largely constant power at low speeds and stalling is prevented.