Basic knowledge

Machine dynamics

Machine dynamics play a prominent role in modern mechanical engineering. The requirements of lightweight construction and ever greater power-to-weight ratios make machines particularly susceptible to harmful vibrations. Machine dynamics provide ways and means to address these problems.

What are machine dynamics?

Machine dynamics refer to the study of a system's motion based on the forces acting on the system.

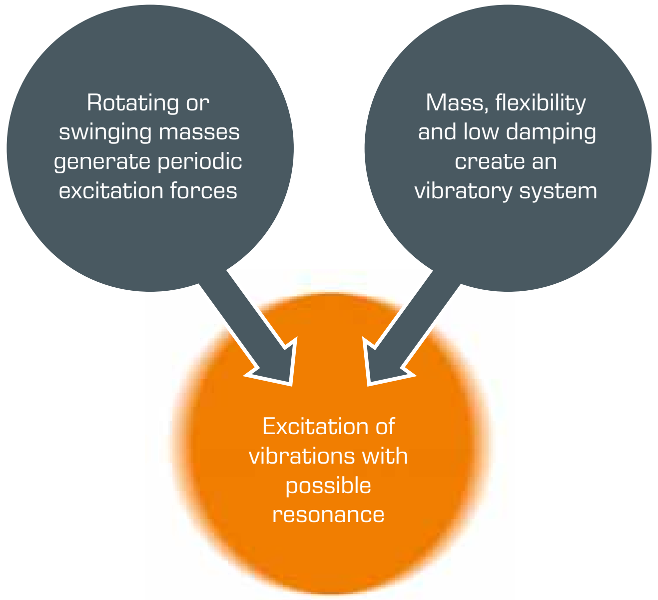
Machine dynamics apply knowledge of engineering mechanics, especially dynamics, to the problems of real machines. The effect of inertia and the occurrence of vibrations play a major role here. Machine dynamics make it possible to predict the vibrational behaviour of a machine and, where possible, to compensate it. Depending on the task, the vibrations may be desired (shakers, vibrating conveyors) or undesired (engines, turbines).

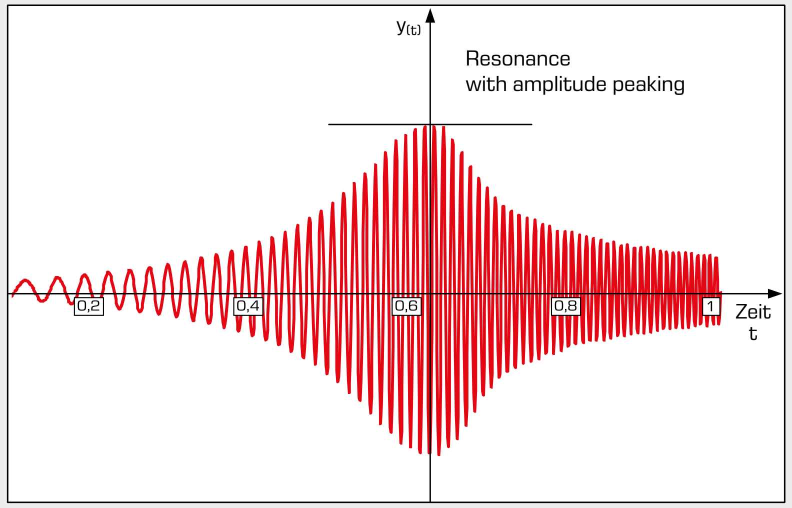
Methods from vibration measuring technology are used to assess and evaluate vibrations. There are also close links to the fields of engineering design, machine elements and drive systems.

When do vibration problems occur?

Vibration problems may occur if the following two conditions are met:

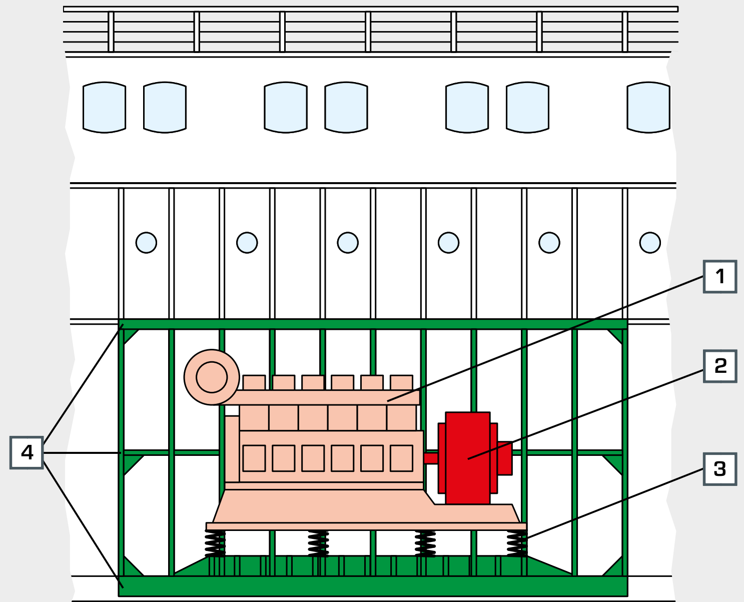
- periodic excitation forces
- vibratory system





The illustration shows the increase in vibrations when passing through the resonance of a vibratory system.
The very high vibration amplitudes can lead to the destruction of the machine. In practice, therefore, such resonances or critical speeds – if they cannot be avoided – must be quickly surpassed.

Measures to avoid vibration problems



Minimising undesired vibrations using the example of a ship's engine system:

1 diesel engine equipped with mass balancing,
2 balanced generator, **3** spring-loaded support for vibration isolation,
4 reinforced ship structure to make the system more rigid

Vibrations should be combated at the source wherever possible. Thus, the procedure should follow the priorities presented here:

- minimise excitation forces by balancing or mass balancing
- prevent propagation of the forces by isolating the vibrations or absorbing the vibrations
- reduce vibratory capacity of the system by making the components more rigid, applying additional mass or using dampers

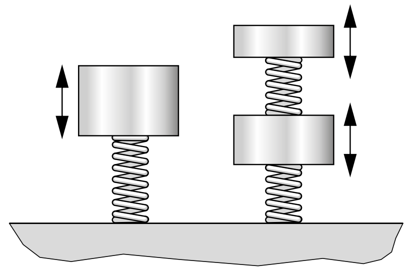
Basic knowledge

Machine dynamics

In machine dynamics, real machines are represented by theoretical models. More often than not, however, machines are very complicated and not easy to calculate. By simplification and abstraction, mathematical models can be obtained for both vibratory systems and for the sources of excitation forces. Using these mathematical models, it is relatively quick and easy to predict the behaviour of the machine.

Linear vibratory system with one or more degrees of freedom

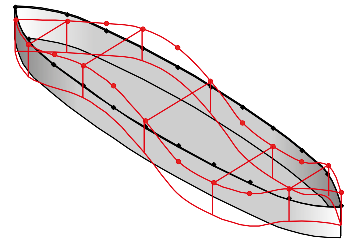
The simplest model of an vibratory system is the spring-mass system. This model provides many insights into the behaviour of an vibratory system. Often the rigidity and mass distributions of a real system can be described sufficiently well by using concentrated point masses and inertia-free springs.



Spring-mass system

Continuous vibratory system

Similarly, simple systems exist for continuous vibration systems such as a ship's hull. In this case, a simple-beam model provides initial indications of the vibratory behaviour when excited by ocean waves. Natural frequencies and their associated natural modes are of interest here.

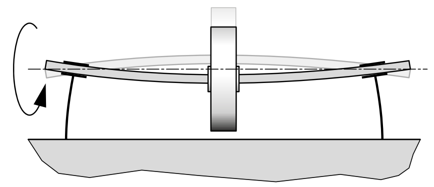


Second order natural frequency of a ship's hull

Rotor dynamics

Rotating machines can cause vibrations due to rotating masses. In elastic rotors, the rotating inertia forces can cause bending vibrations and resonances. Similarly, a non-uniform rotation can cause torsional vibrations.

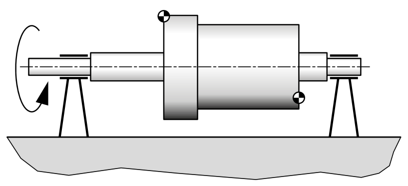
Knowledge of bending-critical and torsion-critical speeds is essential for the design and subsequent operation of the machine.



Elastic shaft with mass disk

Balancing rotors

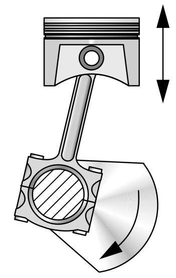
The vibrations on rotating machines can be reduced through balancing. In this process, the excitation forces caused by the rotating masses are minimised. We attempt to match the centre of gravity and the axis of inertia of the rotor with the axis of rotation by applying or removing masses. This method is particularly useful, as balancing eliminates the cause of the vibrations.



Rotor with points for mass balancing

Reciprocating engines

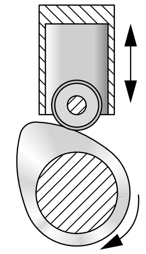
Machine dynamics play an important role in reciprocating engines. Various inertia forces are produced by large back-and-forth and rotating masses. These forces can cause considerable vibration problems in a poor design. The resulting inertia forces can be kept small by distributing the masses over several cylinders, suitable kinematic ratios and the arrangement of balancing masses. This enables a low-vibration operation of the reciprocating engine.



Crank mechanism

Cam mechanism

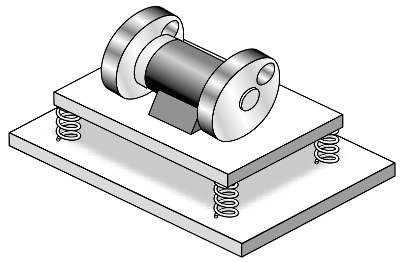
Cam mechanisms are used to convert a rotating motion into a back-and-forth motion. Cam mechanisms are used as a valve drive in engines or in packing machines. Poorly designed cam mechanisms produce high accelerations and inertia forces. This results in vibrations and noise. The application of machine dynamics allows a design with the lowest possible loads and vibrations.



Camshaft with roller plunger

Machine foundations and supports to isolate vibrations

Machine foundations or supports are designed so that the transmission of vibrations from the machine to the environment is largely prevented. This prevents unpleasant vibrations of buildings, plants or motor vehicles. This is known as vibration isolation. Using the methods of machine dynamics, the properties of the machine supports are determined and the effects on the environment are calculated.



Imbalance generator on spring-loaded foundation

Contents of machine dynamics

Linear vibratory systems with one degree of freedom	TM 150, TM 150.02, TM 155
Linear vibratory systems with several degrees of freedom	TM 150, TM 140, TM 182
Vibrations in continuous systems	HM 159.11, TM 625
Rotor dynamics, bending-critical speeds	TM 620, TM 625, PT 500.10
Balancing technology	TM 170, PT 500, PT 500.10, PT 502
Machine dynamics in reciprocating engines	TM 180, PT 500.16
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Vibration measuring equipment and fundamentals of frequency analysis	PT 500 ff, HM 159.11, TM 182
Machinery status monitoring	PT 500 ff, PT 501

GUNT offers an extensive range of experimental units in the field of machine dynamics. The programme is based on a typical curriculum for machine dynamics. Furthermore, units are available for vibration measuring methods and machine diagnosis.