Permanent-magnet-excited electrical devices

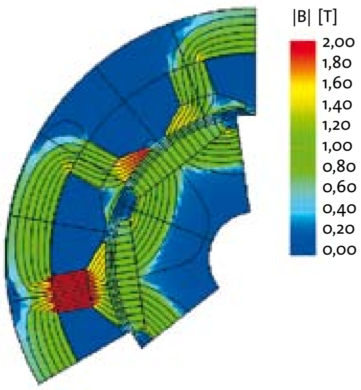
Permanent-magnet-excited electrical devices are becoming more and more important as demands for improved mechanical and energy efficiency grow. Nevertheless, the required properties can no longer be determined or simulated exclusively by classical analytical methods. The use of software tools based on the finite element method (FEM) is therefore particularly useful. The use of such methods enables the correct determination of the non-linear behaviour of materials – particularly in the case of complex laminations and saturation – and enables their optimisation to achieve the device parameters required.

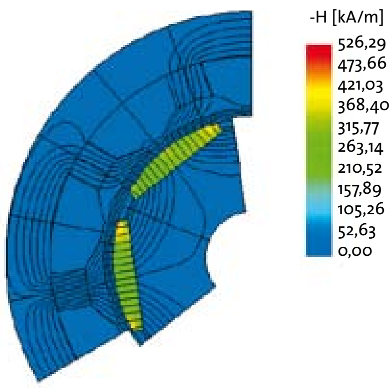
The simulation of the magnetic field at the beginning of a development process is essential to ensure the optimum design of the magnetic circuit. In addition to the ideal utilisation of the materials employed, this step is also used to determine other important properties, such as the rotor-position-dependent induced voltage.

Typical examples of simulation and design

Calculation of induction distribution and demagnetisation

In the example shown here, it is noticeable that the stator teeth at certain rotor positions are too strongly saturated. The logical consequence is that the stator teeth must be made wider to avoid this problem. It can also be seen that there is no risk of demagnetisation for the magnets.

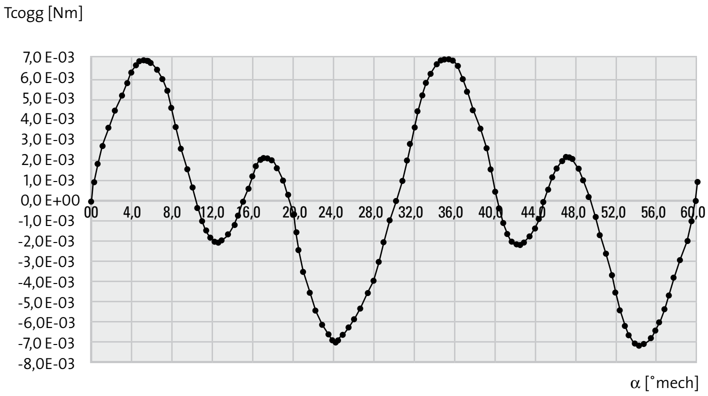




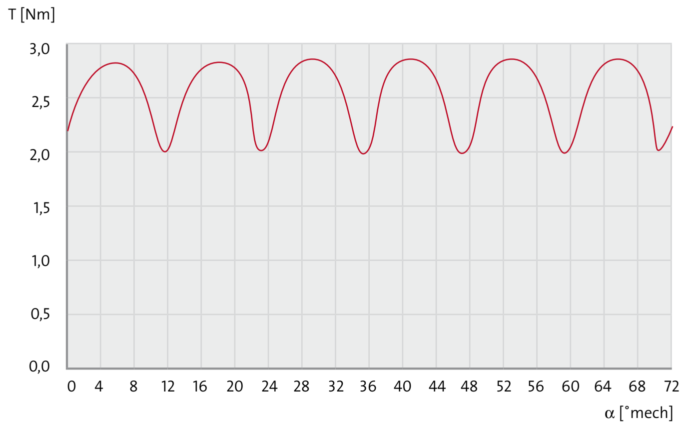
Cogging torque/torque curve/electrical properties

In the case of grooved laminates used in combination with permanent magnets, cogging torque effects occur that may or may not be desirable, depending on the intended application. The cogging-torque curve and its maximum are determined by material properties and the geometry. As a result of the pole/groove combination, the following example shows a cogging-torque period of 30°.

Cogging-torque curve



Torque curve

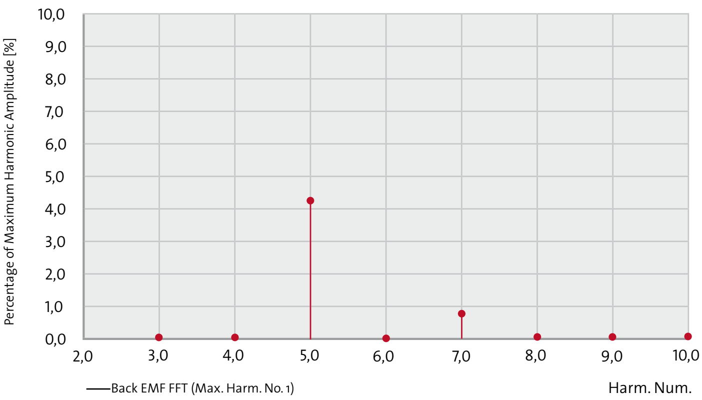


Modifications to various parts of the geometry are an appropriate solution for the reduction of cogging torque. However, this also causes changes in the induced voltage and its harmonics, which must also be appropriately analysed.

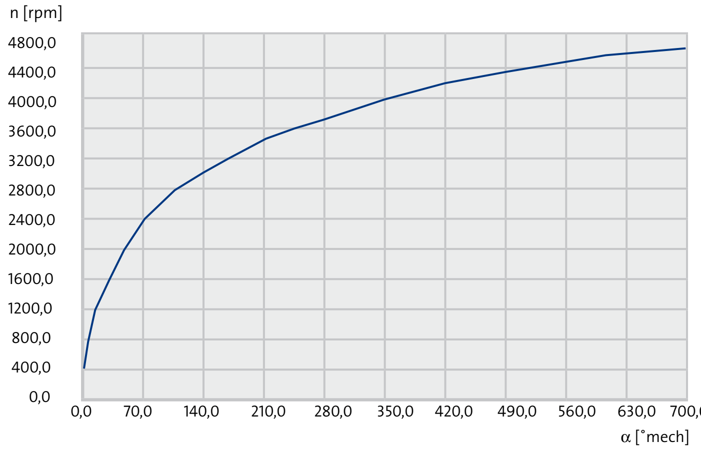
Additional analyses

Further computations and evaluations in the time domain, e.g. with PWM-controlled motor voltage, complement and finalise the simulation model. The following illustrations show the dynamic motor behaviour in the starting phase with the depiction of rotational speed, torque and phase current simulated for the rotor position and in the time domain.

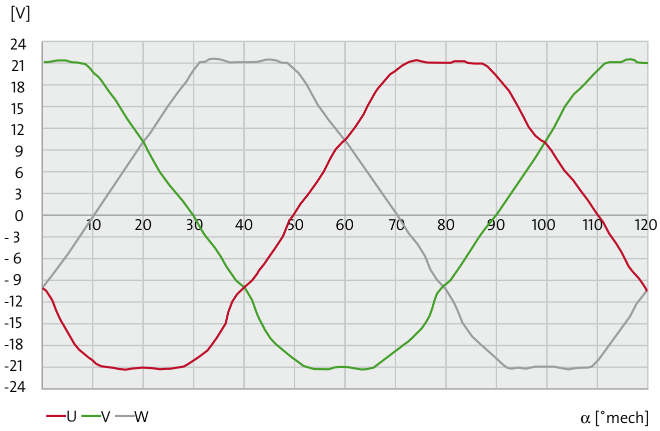
Induced voltage harmonics



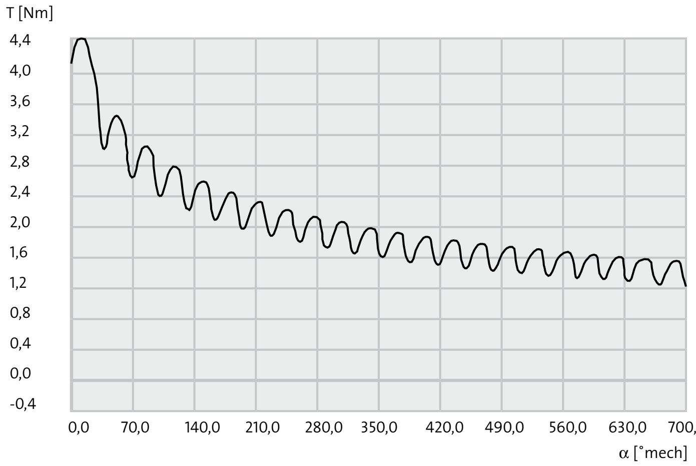
Rotational-speed curve



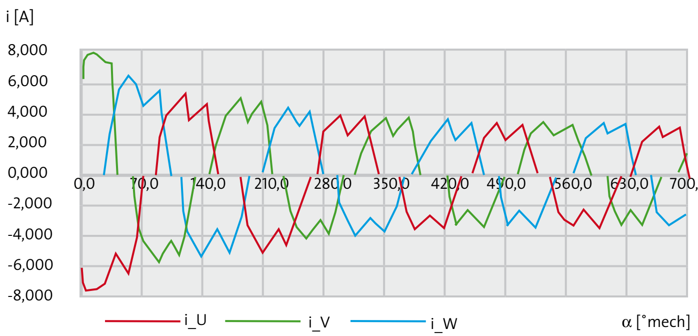
Induced voltage curve



Torque curve



Phase-current curve



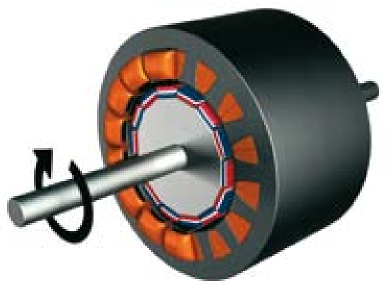
Design examples for PM-synchronous motors and generators

Internal rotors are employed when applications demand extreme speed ranges and dynamic properties, and when motors are to be designed for a high protection class.

Some typical applications for this type are servo-motors, actuators in automated systems and in packaging technologies.

An **external rotor** is the appropriate choice for slow-moving drives with the highest torque requirements.

They possess good speed constancy as a result of their higher moment of inertia. They are suitable for all applications in which the rotor can be directly employed as the power take-off, for example, as it is usually the case in ventilators or pumps.



Internal rotor motor with 15 grooves and 14 surface magnets

External rotor motor with 9 grooves and 12-pole ring magnet

Internal rotor motor with 6 grooves and 4 embedded magnets

External rotor motor with 6 grooves and 8 rectangular magnets

Internal rotor motor with 15 grooves and 14 embedded magnets, 'spoke design'

A **linear motor** is employed when a transverse motion without transmission components is required to achieve extreme positioning accuracy and high positioning speeds.

By the combination of two axial directions, it is easy to realise arbitrary motion and positioning in a single plane. Linear motors are therefore predominantly employed in automation technologies.

Single-phase motors with bipolar ring magnets are generally employed as reluctance motors.

They are therefore suitable for applications requiring a rotational direction that only needs to overcome a low starting torque. They are typically employed as cooling-fan motors in electronic systems and as aquarium pumps.

Linear motor with 6 grooves and n magnets

Single-phase motor with bipolar ring magnet

Practical example
Internal rotor motor with 6 grooves and 8 surface magnets