maxon DC motor and maxon EC motor
Key information

The motor as an energy converter

The electrical motor converts electrical power P_{el} (current *I* and voltage *U*) into mechanical power P_{mech} (speed *n* and torque *M*). The losses that arise are divided into frictional losses, attributable to P_{mech} and in Joule power losses P_J of the winding (resistance *R*). Iron losses do not occur in the coreless maxon DC motors. In maxon EC motors, they are treated formally like an additional friction torque. The power balance can therefore be formulated as:

$$P_{el} = P_{mech} + P_J$$

The detailed result is as follows

$$U \cdot I = \frac{\pi}{30\,000}\, n \cdot M + R \cdot I^2$$

Electromechanical motor constants
The geometric arrangement of the magnetic circuit and winding defines in detail how the motor converts the electrical input power (current, voltage) into mechanical output power (speed, torque). Two important characteristic values of this energy conversion are the speed constant k_n and the torque constant k_M. The speed constant combines the speed *n* with the voltage induced in the winding U_{ind} (=EMF). U_{ind} is proportional to the speed; the following applies:

$$n = k_n \cdot U_{ind}$$

Similarly, the torque constant links the mechanical torque *M* with the electrical current *I*.

$$M = k_M \cdot I$$

The main point of this proportionality is that torque and current are equivalent for the maxon motor.
The current axis in the motor diagrams is therefore shown as parallel to the torque axis as well.

See also: Technology – short and to the point, explanation of the motor

Units
In all formulas, the variables are to be used in the units according to the catalog (cf. physical variables and their units on page 42).

The following applies in particular:
– All torques in mNm
– All currents in A (even no-load currents)
– Speeds (rpm) instead of angular velocity (rad/s)

$P_{el} = U \cdot I$ $\qquad P_J = R \cdot I^2$ $\qquad P_{mech} = \frac{\pi}{30\,000} M \cdot n$

Motor constants
Speed constant k_n and torque constant k_M are not independent of one another. The following applies:

$$k_n \cdot k_m = \frac{30\,000}{\pi}$$

The speed constant is also called specific speed. Specific voltage, generator or voltage constants are mainly the reciprocal value of the speed constant and describe the voltage induced in the motor per speed. The torque constant is also called specific torque. The reciprocal value is called specific current or current constant.

Motor diagrams

A diagram can be drawn for every maxon DC and EC motor, from which key motor data can be taken. Although tolerances and temperature influences are not taken into consideration, the values are sufficient for a first estimation in most applications. In the diagram, speed *n*, current *I*, power output P_2 and efficiency η are applied as a function of torque *M* at constant voltage *U*.

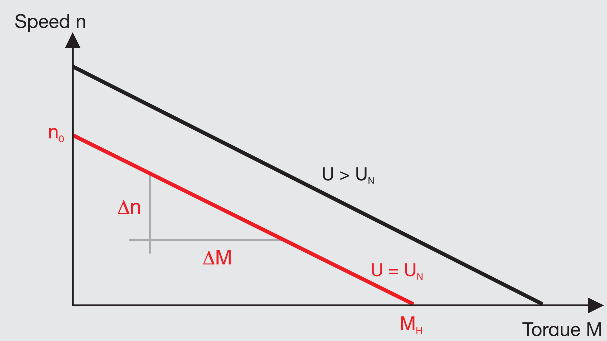
Speed-torque line
This curve describes the mechanical behavior of the motor at a constant voltage *U*:
– Speed decreases linearly with increasing torque.
– The faster the motor turns, the less torque it can provide.
The curve can be described with the help of the two end points, no-load speed n_0 and stall torque M_H (cf. lines 2 and 7 in the motor data).
DC motors can be operated at any voltage. No-load speed and stall torque change proportionally to the applied voltage. This is equivalent to a parallel shift of the speed-torque line in the diagram. Between the no-load speed and voltage, the following proportionality applies in good approximation

$$n_0 \approx k_n \cdot U$$

where k_n is the speed constant (line 13 of the motor data).

Independent of the voltage, the speed-torque line is described most practically by the slope or gradient of the curve (line 14 of the motor data).

$$\frac{\Delta n}{\Delta M} = \frac{n_0}{M_H}$$



Derivation of the speed-torque line
The following occurs if one replaces current *I* with torque *M* using the torque constant in the detailed power balance:

$$U \cdot \frac{M}{k_M} = \frac{\pi}{30\,000}\, n \cdot M + R \cdot \left(\frac{M}{k_M}\right)^2$$

Transformed and taking account of the close relationship of k_M and k_n, an equation is produced of a straight line between speed *n* and torque *M*.

$$n = k_n \cdot U - \frac{30\,000}{\pi} \cdot \frac{R}{k_M^2} \cdot M$$

or with the gradient and the no-load speed n_0

$$n = n_0 - \frac{\Delta n}{\Delta M} \cdot M$$