7.5 Characteristics of maxon motors and product overview

Operating ranges

The maximum permisssible speed n_{max} and the rated torque M_N (in the sense of a maximum permissible continuous torque) are the two values that limit the continuous operating range of a maxon motor. Operating points in this range are thermally not critical and generally do not result in increased wear on the bearings or the commutation system.

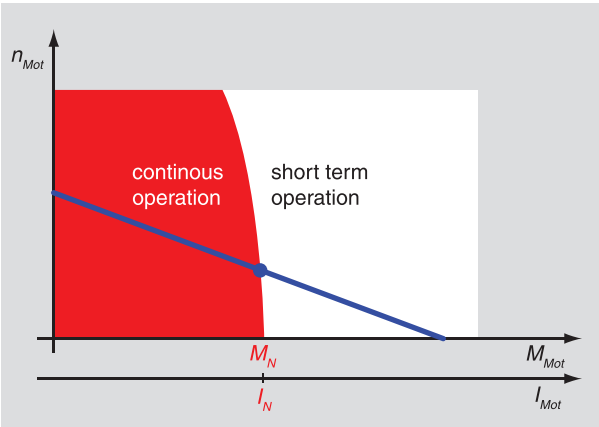

Figure 7.5: Operating range diagram of maxon motors: Continuous operating range (red), intermittent operating range (white). The figure also shows a speed-torque line with the corresponding rated operating point (blue).

Rated current and rated torque

The rated current of maxon motors is determined as the maximum current that can continuously be applied without overheating the motor. The rated torque is correspondingly defined as the maximum permissible continuous torque.

The heat that is generated in the winding by the motor current is dissipated to the atmosphere via the magnetic return path (housing) and flange. The critical component from a thermal standpoint is the winding construction without iron core. This type of coil may be deformed at temperatures above the maximum permissible winding temperature T_{max} which ultimately leads to the failure of the motor. On maxon EC motors and graphite-brush DC motors with higher permissible current loads, the winding is reinforced with a glass fibre bondage. This allows winding temperatures up to 125°C (in isolated cases up to 155°C). Motors commutated with precious metal brushes are designed for a lower current load, so that winding temperatures up to 85°C are permitted and coil stability is ensured by an adhesive tape.

In continuous operation the current must be restricted so that the thermal losses that occur can be dissipated and the rotor temperature remains below the maximum permissible value. This condition defines the rated current I_N, at which the maximum winding temperature is reached under standard conditions (25°C ambient temperature, without heat dissipation via the flange, unrestricted air convection). Motor currents below I_N lead to lower winding temperatures; higher motor currents lead to higher winding temperatures.

The continuous operating range can be extended toward higher torques and higher currents if heat dissipation is improved by additional heat sinks such as installation on thermally conducting surface or forced cooling (see Figure 7.3). In such cases the commutation system must be designed as well for these high currents.

The rated torque M_N has a meaning equivalent to the rated current I_N. While I_N depends closely on the wire diameter used, M_N is practically independent of the winding used within a motor type. M_N is therefore a characteristic value for the motor type and an important selection criterion. The motor diagram in the catalogue – though strictly applicable for one winding only – can also be applied with some degree of approximation for the entire series of windings (with the exception of the current scale).

The brush system of DC motors can limit the rated current in windings made of large diameter wire and correspondingly low resistance. In these cases the commutation cannot handle the high current without aging quickly. The rated torque of these windings is therefore lower than normal for this motor type.

Influences on the rated torque

The rated torque in the maxon catalogue M_N represents the maximum permissible continuous torque. Under standard conditions at 25°C the motor reaches the maximum permissible temperature. The rated torque varies as a function of the ambient temperature T_{Amb} and mounting conditions; a higher ambient temperature results in a less efficient dissipation of heat and consequently a lower continuous torque.

Similarly the details of the thermal coupling have an influence on the thermal resistance R_{th2} between housing and ambiant and thus on the rated torque. As the heat dissipation improves, i.e. at a lower R_{th2}, the rated torque of the motor increases. The thermal resistance R_{th2} can easily be reduced by one-half by forced cooling or thermal coupling to a heat conducting (metal) seat.

Figure 7.3 illustrates how the influence of the ambient temperature on the rated torque can be taken into consideration. It also shows the influence of the thermal coupling between motor and ambiant when modified from standard conditions.

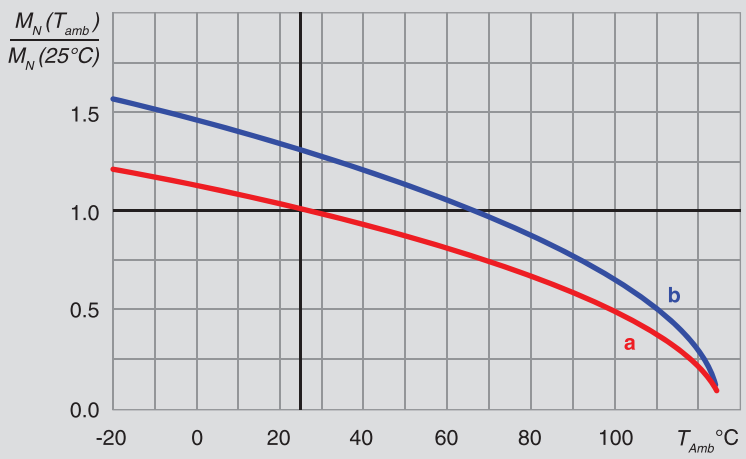

Figure 7.3: Rated torque M_N (with reference to the catalogue value) as a function of the ambient temperature using the example of a motor with a maximum winding temperature of 125°C.

a) With standard mounting on plastic flange and free air convection.

b) With thermal resistance R^*_{th2} reduced by 50% (heat sink).

Max. permissible speed

On the DC motor, the maximum speed of rotation is limited by the commutation system. At very high speeds, the commutators and brushes wear more rapidly and the life of the motor is reduced. The reason for these effects is twofold. The mechanical friction increases at elevated operating speeds and the added brush bounce increases the magnitude of the wear due to electro-erosion. At higher speeds, the induction voltages are higher and the arcing is more pronounced. To keep the peripheral velocity on the commutator as low as possible and to guarantee a smooth commutation even at high speeds of rotation, the commutator diameter is designed to be as small as possible. The maximum permissible speed n_{max} is calculated from empirical values for the maximum peripheral velocity on the commutator and from the commutator diameter. Speeds above the maximum permissible speed are possible, although they generally come at the expense of a greatly reduced motor life.

With the EC motor, the following factors are included in the determination of the maximum permissible speed

- The permissible unbalance of the rotor
- The permissible maximum bearing load which depends on the size of the bearing used
- The required bearing life of 20 000 operating hours
- The mechanical stability of the rotor (magnets) with respect to the centrifugal forces at high speeds of rotation.

Intermittent operation

Because the thermal reaction time of the winding is relatively low (several seconds), brief intermittent current spikes exceeding the rated current I_N are permitted. As long as the maximum permissible winding temperature T_{max} is not exceeded the winding will not be damaged.

Intervals with elevated torque (or overload) may be applied only for a limited period of time. The order of magnitude of the permissible overload duration is in the range of a few seconds for the smallest maxon motors (10-13 mm diameter) up to about a minute for the larger motors (60 mm, 75 mm diameter). The thermal time constant of the winding is a measure for the length of such permissible intermittent or short-term overloads.

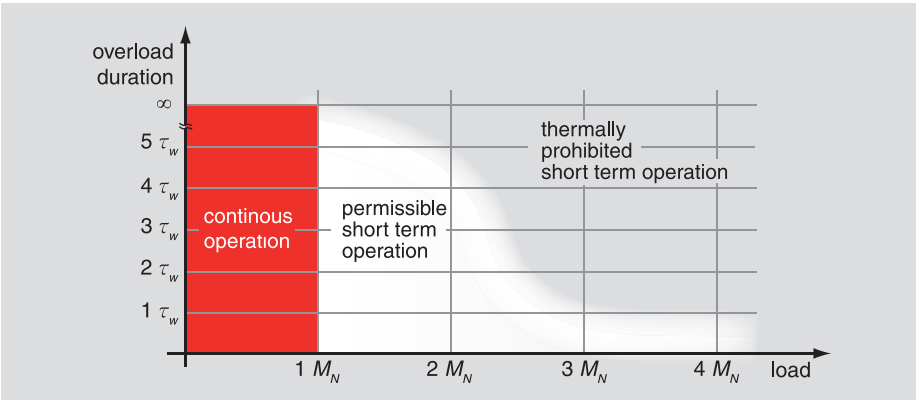

Figure 7.6: Permissible length of intermittent operation as a function of the overload torque (current) of the motor. (The time scale is indicated with reference to the motor in units of the thermal time constant of the winding τ_W. The load is indicated in units of the rated motor torque.) Note the sharp decrease of the permissible duration of overload operation when the motor is operated at more than twice the rated torque. The gradual transition between the acceptable and thermally prohibited intermittent operation suggests that the details of the thermal interface must also be taken into consideration.

The calculation of the exact duration of the allowable overload depends almost entirely on the motor current and the starting temperature of the winding. Figure 7.6 shows in a simplified representation, which is sufficient for most applications, whether an overload is thermally possible or not. In order that the diagram can be applied to all motors the load and load duration are indicated in motor-specific units. At four times overload, there are still on-periods of longer than 1 s acceptable, assuming the thermal time constant of the winding to be 4 s. Starting and braking processes and brief movements frequently occur so quickly that from a thermal point of view the motor can be overloaded by multiples of the rated torque.