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DC Motor Selection for Dynamic Motion Control Applications

By Dr. Urs Kafader, Technical training maxon Switzerland.

Finding the right motor is one of the core elements in the selection of dynamic drive components. Due to their high starting torque maxon DC motors with or without brushes are the perfect matches for highly dynamic servo applications. Once the requirements of the application are specified and a general motion control strategy is established, there are a few rules to be respected to get the optimum motor.

Torque and motor size

Often motors are selected from the calculated mechanical power, i.e. from the speed and torque requirement. This can lead to totally wrong results. As an example, take an application running at 25W mechanical power. The maxon EC 22 with a rated power of 40 W would perfectly fit. The power rating of the motor is based on a high speed of approx. 22'000rpm and a nominal torques of about 18mNm. However, the motor overheats if the required load torque is 40mNm (together with a load speed of 6000rpm this results in 25W!) which is more than twice the nominal torque of the motor.

This leads us to rule no. 1: Select a motor type big enough to fulfill the torque requirements. If necessary use a gearhead to reduce the torque to an acceptable level for the motor. Essentially, there are two torque values to check. The first one is based on thermal considerations. Make sure that the average load torque of the application lies below the rated or nominal torque of the motor. In applications where a working cycle is constantly repeated, the RMS average of the load torque including dwell must be contained within the continuous operating range.

The second torque restriction concerns the peak load. For short period of times, the motor can be overloaded without the risk of overheating. Although the details of this overload characteristic depend on the motor design we may state general rule no.2 as follows: Overloading a DC motor by a factor of 2 to 3 for several seconds is possible; the larger the motor, the longer the overload may be.

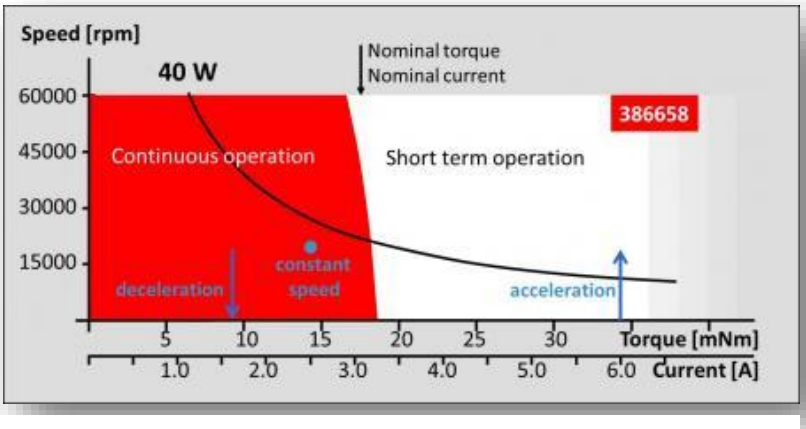

Figure 1: The continuous and short term operating ranges of a maxon EC 22 motor. Essentially, the power rating of 40 W is somewhat arbitrary (black hyperbola of constant power). In blue the load operation points for a speed profile with high acceleration torque are added as well. Observe the current scale in parallel to the torque axis reflecting the fact that DC motor current and produced torque are strictly proportional.

Covering all operation points

At given voltage applied to a DC motor, the speed decreases linearly with increasing motor torque. The motor speed is highest at no-load. The produced torque is largest at start-up allowing for very high acceleration rates and resulting in the dynamic behavior. Changing the applied voltage produces a parallel shifts this speed-torque line (see figure 2). Hence, any required point of motor operation can be achieved simply by varying the applied motor voltage. In servo applications, that's what the motion controller that takes care of.

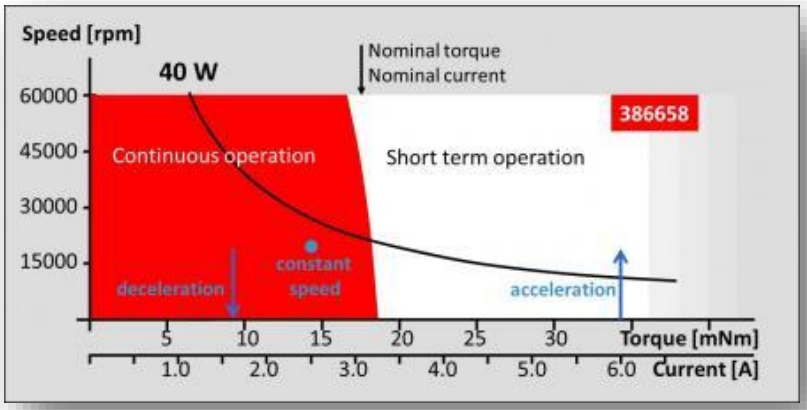

Figure 2: The speed-torque line of a DC motor at the maximum motor voltage (red) and the area of achievable operation points (yellow). The brown line represents the speed torque line at a reduced voltage needed to run the motor at constant speed and torque. Also indicated is the reserve between the maximum speed torque line ant the extreme operation point at the end of acceleration.

Rule no. 3: Make sure that you can cover all the operation points in your application with the maximum available voltage at the motor. Typically, the most critical point is at the end of an acceleration process where the speed and the required torque are highest. The maximum motor voltage may be limited by the power supply used, the maximum supply voltage of the controller and the voltage drop in the controller.

Thick wire –thin wire

For a given motor type or size the mechanical characteristics are quite uniform while the electrical properties can vary a lot depending on the winding used. With a low resistance winding a wide range of operation points can be covered with the motor voltage available; but only at the cost of a lot of current needed to produce the torque. A high resistance winding on the other hand requires a higher voltage but lower currents. Since "current is expensive, voltage is for free" rule no. 4 states the following: Opt for the winding with the lowest current consumption but still fulfilling the third rule with some head room for the controller ("reserve" in Figure 2). "Current is expensive" means that a higher current consumption needs a larger power supply, bigger controller and more elaborate shielding of cables which all adds to the costs. In this context also make sure that the available current from power supply and controller is high enough to cover the maximum required torque.

With/without brushes

In motion controlled dynamic servo applications mostly brushless motors will be selected exhibiting a very high service life and reliability as well as allowing higher speeds.

Brushed motors run without electronic commutation, the control electronics can be made simpler and cost effective. If the service life requirements are not extremely high brushed motors can still have advantages regarding small size. Graphite brushes are found in larger motors and are better adapted to frequent stat-stop applications. Precious metal brushes are used in small size motors below 10W and are best used for continuous operation at moderate load.

These are a few basic considerations just regarding DC motor selection. There is much more to be observed when it comes to the selection of a complete drive system. Controller and feedback strategies, mechanical layout as well as ambient conditions and boundary restrictions may have an impact on motor sizing.

The forthcoming seminars on "DC Servo Motor Sizing Made Easy" A Practical 1/2 Day Course presented by Dr. Urs Kafader, maxon provides the practical information you'll need to successfully select the right DC motor -- be it

brushed or brushless -- for your application. You'll learn about the interpretation of motor data and how you can use this information for motor sizing. Whether you need high speed and dynamics or just high torque, this seminar will teach you to size a motor + drive with just the right power reserves, avoiding costly oversized motors.

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