PL 3 - DC motors (brushed) - Selection

Objectives: Selection of a PM (permanent magnet) DC, brushed motors, using a step-by-step procedure.

Documents available

PL classes: 1) EN_2237_CXR_DFF.pdf 2) EN_1741_CXR_DFF.pdf

Web sites: www.faulhaber.com
www.maxonmotor.com
https://www.crouzet.com/products/dc-motors/

Selection and sizing of electric motors

The choice and specification of a certain type of electric motor, for a given application, involves several considerations to be taken into account, from the characterization of the requirements imposed by the load to be driven, the power supply and control conditions of the defined driving system and the characteristics of the motor series available. As a first approach, we will consider some general principles and a procedure for dimensioning low-power permanent magnet DC motors, based on the recommendations of manufacturers of this type of electric motor (eg Faulhaber-Micromo; Crouzet...)

A- General principles

(1) Load requirements (constant, variable, …)

(2) Restrictions on maximum temperatures of motor frame and windings

(3) Existing standard motor series

(4) Motor technical specifications:

- power, duty cycle, velocity, torque, voltage, current, …;
- rated and maximum, or minimum, values;
- sizes and weight;
- …

B- Selection and specification of PM-DC, brushed, motors

B1- General characteristics

- Available series of small motors
- High starting torque
- Torque decreases with increasing velocity (motor velocity adjusts to motor load)
- Linear relation between torque and velocity
- Linear relation between torque and current
- Motor efficiency is maximum at high velocities and low torques
- Maximum power is not at maximum efficiency
- Possibility of operation above, or below, the rated values

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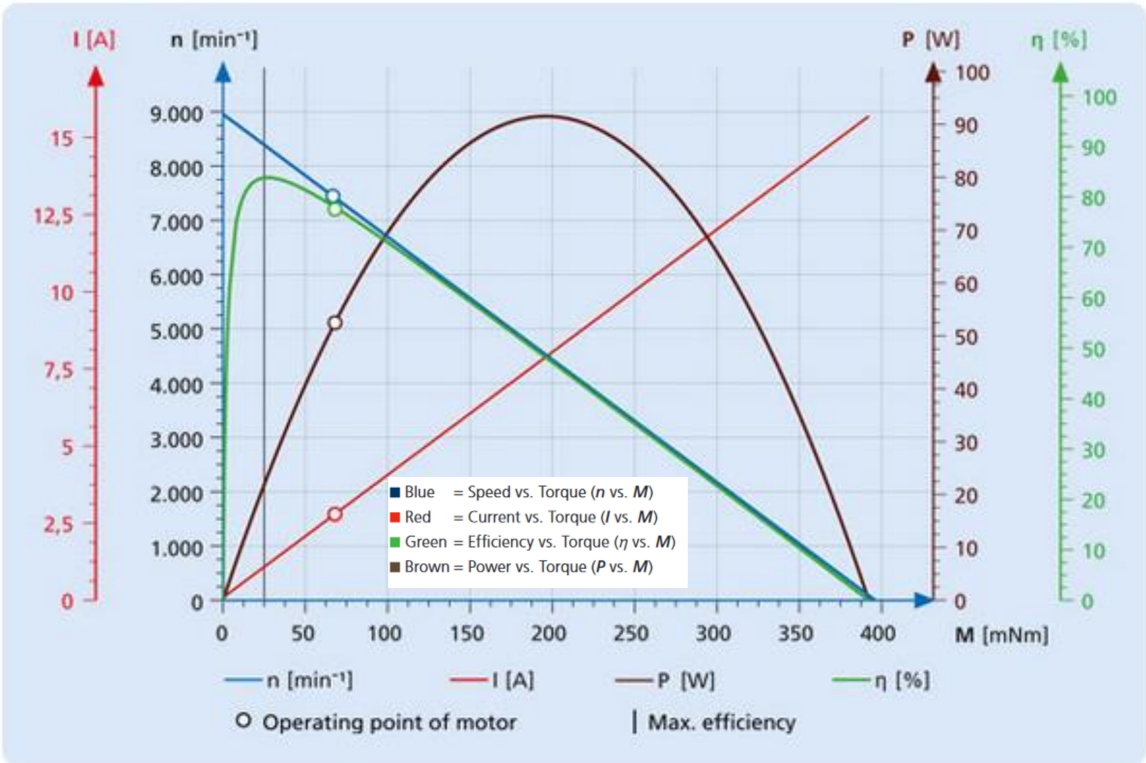
- Example of characteristic curves



Note: Note how all four solid plots change as a result of increased resistance in the copper windings and weakened torque output, due to heat rise. So your results may differ slightly depending on whether your motor is cold or warm when you plot your graphs.

[https://www.faulhaber.com]

Based on this representation, of the characteristic curves, of a permanent magnet DC motor complete below the values for the following characteristics:

(1) Maximum power: ________ [W]
(2) Maximum torque: ____________ [mNm] __________ [Nm]
(3) Maximum velocity: ____________ [rpm] __________ [rad/s]
(4) Torque at maximum power: ____________ [mNm] __________ [Nm]
(5) Velocity at maximum power: ____________ [rpm] ___________ [rad/s]

B2- - Some indications regarding variations in the voltage power supply

- Admissible variations: [$0.5 \times V_n < V < 2 \times V_n$]

Note that if used a lower voltage, the motor will have less power. If used a higher voltage, the motor will have higher power but will heat up more (need to check for motor operating temperature and the motor may be only suitable for intermittent operation). (http://cdn.crouzet-motors.com.s3.amazonaws.com/assets/library/DC-brush-motors.pdf)

- Variations between -25% to +50%, the curves T- ω can be considered to be parallel to the T- ω curves based on rated values. The maximum output power is: $P_{max}=P_n\ (V/V_n)^{2}$; for example, a 20% voltage increase of V_n will give:

$$T_0\big|_{1.2V_n} = 1.2T_0\big|_{V_n}$$

$$\omega_0\big|_{1.2V_n} = 1.2\omega_0\big|_{V_n}$$

$$P_{max}\big|_{1.2V_n} = 1.44P_{max}\big|_{V_n}$$

- It can normally be assumed that the torque-velocity-relation does not change when the supply voltage to the motor changes.

B3- Procedure for choosing a brushed DC motor, permanent magnet, under constant load conditions

Step 1: Specifying the power required by the load (P_{load})

Step 2: Specifying the reference value for the motor power (P_{motor})
- higher than the power required by the load (ex. P_{motor} =[1.5 to 2]·P_{load})

Step 3: Selecting a motor from a motor manufacturer's catalogue
- identify the torque-velocity characteristic curves (T, ω), for the available voltage supply
- verify the velocities ratio reference value ($\omega_{load} / \omega_0 > 70\%$)

Step 4: Repeat calculations with data from the selected motor
- include the no-load torque, or current,
- verify the velocity when taken into account the total load (current or torque)

Step 5: Verify the motor heating behavior under the load conditions
- calculate the electric power loss in the armature, due to the current consumption or Joule's law ($P_{loss} = R_a I_{total}^2$)
- calculate the temperature variation associated with the motor's capability to transfer the electric power loss (P_{loss}) to the surrounding environment, using the respective armature and frame thermal resistances (R_{th1} e R_{th2})
- calculate the motor's temperature, taking into account the environment temperature
- check whether the motor can withstand the calculated temperature.

Additional verifications could be required to take into account the frequency of start/stop operations, duty cycle, size, weight, …).

B4- Exercise 1

Using the method described above verify if it is possible to select a motor, from the available catalogue, that is compatible with the following operating conditions:

- *Available supply voltage* — *V =* *30 Volts DC*
- *Load torque* — *T =* *10 mNm*
- *Velocity* — *n =* *6000 rpm*

- Indicate the calculations for each step and represent the characteristic curves, *(T, ω)* and *(T, I)*, of the motor.