

## Chapter 5 - Sizing Criteria

Because of the high performance obtained by the drive/brushless motor set, the dynamic performance of the entire system is strongly influenced by the mechanics of the system itself.

In particular, the following considerations are important:

- the degree of precision depends on the sensor and not on the motor
- the response speed depends on the transmission rigidity (mechanical passband)
- the system audible noise, sometimes very strong, does not depend on the motor and/or on the electronics, but on a mechanical design which is not suitable for the required performance.
- the motor noise is due to continuous acceleration and braking. In such conditions, motor overheating may occur, which may not be due to a too-small motor.
- the passband controlling the drive depends on the mechanics, as it is not possible to stabilize the electronics to a period less than 3 times the ring time of the system mechanical oscillations.

The choice of the mechanical transmission must be carried out, therefore, according to the application. In mandrel applications, with significant transmitted power and marginal dynamic performance, common reducer transmissions are used. In this case, that is the optimum economical choice.

In case of axis applications, where the system dynamic performance is fundamental, the required torque is often equal to the sum of the motor and load inertial torques. The use of a reduction ratio in the transmission reduces, on one side, the load inertia influence, but, on the other, it increases the motor side. In such applications, therefore, direct coupling is normally used. With direct coupling, the system dynamics are influenced by the shaft torsional rigidity and by the relative resonance frequency. The drive and motor are capable of much higher bandwidth than the mechanics.

After choosing the motor and the transmission, it is necessary to check the application. In case of applications whose speed and load are constant, or variable for periods longer than the motor time constant, it is sufficient to check that the maximum load is within the capacity limits stated for the motor and the drive.

On the contrary, in applications where the load changes according to a faster cycle, do the following:

- Trace a cycle speed/time diagram, remembering that the reaching of a precise position or speed value requires, apart from the time set by the system limit accelerations, a settling period equal to 3 times the period of the system passband.
- Refer the system inertia and loads back to the motor axis.
- Calculate the acceleration cycle and the cycle of the relative inertial torques.
- State the cycle torque/time diagram by adding the inertial torques to the loads.

- Calculate from the torque/time diagram the cycle effective torque. If the cycle is made up of n duration segments t1, t2, ... tn, and of their corresponding torques C<sub>1</sub>, C<sub>2</sub>, ... C<sub>n</sub>, the cycle effective torque is given by:

$$C_{eff} = \sqrt{\frac{C_1^2 t_1 + C_2^2 t_2 + \dots + C_n^2 t_n}{t_1 + t_2 + \dots + t_n}}$$

- Calculate, with the same formula, the average quadratic speed.
- Calculate the cycle average torque.
- Calculate the maximum duration period of the cycle maximum torque.
- Calculate the torque required with the cycle maximum speed.
- Calculate the cycle maximum torque.

The motor and the drive have to be checked on the basis of the obtained data.

### 5.1 Motor Check

The motor check phases are:

- check of the peak torque
- thermal Sizing
- electrical Sizing

#### Check of the demagnetization current

Such check is carried out with a direct comparison with the peak current via the formula:

$$I_{demag} = \sqrt{2} \frac{C_{pk}}{K_t}$$

where:

$I_{demag}$	=	motor demagnetization current
$C_{pk}$	=	cycle peak torque
$K_t$	=	motor torque constant

#### Check of the thermal sizing

Check first that the point C<sub>eff</sub>, ω<sub>eff</sub> is within the area of the motor continuous operating range.

In particular, calculate the motor temperature increase, given by the relation:

$$\Delta T_{max} = \frac{65}{L_n} \left[ \left( \frac{C_{eff}}{T_n} \right)^2 L_n + \left( \frac{\omega_{eff}}{\omega_n} \right)^2 L_0 \right]$$

where:

$L_n$	=	motor rated losses
$T_n$	=	motor rated torque
$\omega_n$	=	motor rated speed
$L_0$	=	motor rated losses in ω <sub>n</sub>

If the maximum temperature is higher than the motor maximum, a bigger motor is needed.

**Check of the electric sizing**

In this case, it is necessary to check that at maximum speed, the voltage required by the motor is lower or equal to that supplied by the drive with the minimum expected power supply voltage. The following relation must be satisfied:

$$V_{max} = \sqrt{\left(K_e \omega_{pk} + R_w \frac{C_{pk}}{K_t}\right)^2 + \left(\frac{C_{pk}}{K_t} \frac{P_N}{2} \omega_{pk} L_w\right)^2} \leq E_{min}$$

where:

- $E_{min}$  = minimum voltage supplied by the drive
- $K_e$  = motor voltage constant
- $\omega_{pk}$  = cycle maximum speed
- $R_w$  = motor terminal to terminal resistance
- $C_{pk}$  = cycle maximum torque
- $K_t$  = motor torque constant
- $P_N$  = motor pole number
- $L_w$  = motor terminal to terminal inductance

If such condition is not satisfied, it is necessary to choose a motor with a winding suitable for a higher speed; in this case a higher current will be needed.

**5.2 Check of the Drive Size**

The drive size is chosen according to the torque to be supplied to the motor with a specific winding, from where the needed energy is derived.

The peak and average currents required by the drive are provided by:

$$I_{max} = \frac{C_{pk}}{K_t} \quad I_{ave} = \frac{C_{ave}}{K_t}$$

where:

- $C_{pk}$  = cycle maximum torque
- $C_{ave}$  = cycle average torque
- $K_t$  = motor torque constant

The drive must be in a position to develop continuous and peak currents higher than the calculated values. Remember that the drive maximum current can be compared to  $I_{max}$  only if the relative time is lower than 2 seconds; if not, the drive must have a rated current higher than  $I_{max}$ .

**5.3 Application Example: Flying Cut**

Consider a continuous belt moving cutter.

The cutter is mounted on a carriage. The belt speed is 4 m/s.

The cutter must, with a command, increase its speed till reaching the belt, get synchronized with the belt speed, keep such speed for 300 ms (cutting time), brake and return to the rest position.

The total stroke of the cutter carriage is 5 m. The cutter weighs 80 kilos plus the motor weight.

As the mechanical transmission system is rather complex, it is necessary to provide a speed stabilization time  $T_{st}$  with transients to about 150 ms.

The cutting space with a constant speed is given by:

$$S_t = V_t \times (T_t + T_{st}) = 4 \times (300 \times 10^{-3} + 150 \times 10^{-3}) = 1.80 \text{ m}$$

The carriage will run across the remaining space during its acceleration and deceleration phase. If these two spaces are equal:

$$S_{acc} = S_{dec} = (S_{tot} - S_t) / 2 = (5 - 1.80) / 2 = 1.60 \text{ m}$$

The average speed during the acceleration is:

$$V_{med} = V_{max} / 2 = 4 / 2 = 2.0 \text{ m/s}$$

The acceleration and deceleration times are:

$$T_{acc} = S_{acc} / V_{med} = 1.60 / 2.0 = 0.800 \text{ s}$$

The acceleration (and deceleration) is:

$$a = V_{max} / T_{acc} = 4 / 0.80 = 5.0 \text{ m/s}^2$$

Assuming that the motor weight is about 40 kg, the required inertial power is:

$$F = a \times (M_{carr} + M_{mot}) = 5.0 \times (80 + 40) = 600 \text{ N}$$

The total semi-cycle time is:

$$T_{sc} = 2 \times T_{acc} + T_{st} + T_t = 2 \times 0.800 + 0.150 + 0.300 = 2.05 \text{ s}$$

The transmission is carried out via a pinion and a rack. The pinion dimensions are:

diameter	Dp = 40 mm
length	hp = 30 mm

The speed, acceleration and inertia brought to the motor axis are:

Speed:  $\omega_{max} = V_{max} / (Dp/2) = 4 / (0.04/2) = 200 \text{ rad/s}$

Acceleration:  $m_a = a / (D_p/2) = 5.0 / (0.04/2) = 250.0 \text{ rad/s}^2$

Inertia:  $J = M_{tot} \times (D_p/2)^2 = 120 \times (0.04/2)^2 = 0.048 \text{ kgm}^2$

The pinion inertia is given by:

$$J_p = (D_p/2)^4 \times h_p \times \pi \times \delta = 5.806 \times 10^{-5} \text{ Kgm}^2$$

where  $\delta$  is the density of the material forming the pinion (steel).

Check now a *PacTorq* E182E4 TENV motor with an inertia of 0.0127 kgm<sup>2</sup>.

The total inertia is:

$$J_{tot} = J + J_p + 0.0127 = 0.048 + 5.806 \times 10^{-5} + 0.0127 = 0.0608 \text{ kgm}^2$$

Assuming a pinion efficiency equal to 0.95, the maximum torque (overload) required to the motor is:

$$C_{max} = m_a \times J_{tot} / 0.95 = 250.0 \times 0.0608 / 0.95 = 15.99 \text{ Nm}$$

The average (continuative) and effective torques are therefore, supposing null the torque at constant speed:

$$C_{med} = C_{max} \times T_{acc} \times 2 / T_{sc} = 12.47 \text{ Nm}$$

$$C_{eff} = C_{max} \times (2 \times T_{acc} / T_{sc})^{1/2} = 14.13 \text{ Nm}$$

As the cycle effective torque is higher than the motor rated torque at nominal speed, a motor of a bigger size must be chosen.

Repeating the operations for a E183E4 TENV motor with an inertia of 0.016 kgm<sup>2</sup>, the obtained average torque is 13.84 Nm while the effective torque is 15.69 Nm. The motor is therefore suitable for the application, considering that its nominal torque at nominal speed is 18.4 Nm.

Given the torque constant at rated temperature  $K_t = 3.37 \times 0.9 = 3.03 \text{ Nm/A}$ , the average and maximum current absorbed by the motor are:

$$I_{max} = C_{max} / K_t = 5.85 \text{ A}_{rms}$$

$$I_{med} = C_{med} / K_t = 4.57 \text{ A}_{rms}$$

The drive size to be used with the present application is therefore PX-7.

**NOTES:**

## Chapter 6 - Maintenance

### 6.1 Care

The FlexMax series drives must be installed according to the relevant installation regulations. They do not require any particular maintenance. They should not be cleaned with a wet or moist cloth. The power supply must be switched off before cleaning.

### 6.2 Service

The screws of all terminals on the drive should be re-tightened two weeks after initial commissioning. This should be repeated each year.

If the drives have been stored for more than three years, the capacitance of the intermediate circuit capacitors may have been impaired. Before commissioning these drives, it is advisable to supply power to the drives for at least two hours in order to regain the capacitor original ratings. To this purpose apply an input voltage **without applying any load on the output**.

After these steps, the drive is ready to be installed without limits.

### 6.3 Repairs

Repairs of the drive should only be carried out by qualified personnel (suggested by the manufacturer).

If you carry out a repair on your own, observe the following points:

- When ordering spare parts do not only state the drive type but also the drive serial number. It is also useful to state the type of the regulation card and the system software version.
- When changing the cards ensure that the positions of switches and jumpers are observed!

### 6.4 Customer Service

For customer service, please refer to your Powertec Sales Office, Distributor, or Service Agent.

**NOTES:**