



USER MANUAL DC TORQUE MOTOR

The present manual shows an opportunity for the servomechanisms builders of choosing the DC torque motors, with high performances, low price and immediate delivery.

ICPE SA Department 4 designs and manufactures DC permanent magnets torque motors whose windings are optimized so that a maximum torque within overall size (housing outside diameter): 1.5 inch...5.1 inch can be obtained.

1. Features of the DC torque motor.

These motors are designed in such a way as to function in direct-drive construction. The fixed element – the stator, is equipped with permanent magnets and the rotor with a DC specific winding which is connected to an extra-flat commutator – brushes system; the rotor can perform a continuous rotation and the main advantages of this construction are:

- Lack of the gear or the mechanical multiplier;
- Direct mounting on the leading shaft;
- High useful mechanical torque at low speeds;
- Big ratio: torque/inertia moment;
- Linear characteristic of the useful mechanical torque function the speed;
- Big ratio: useful mechanical torque/power;
- Time electrical constant: small;
- Noise and vibration- free operation;
- Simple but solid construction.

This electro-mechanical construction allows the servosystem designer to obtain the following advantages:

- Rigid coupling;
- Quick response to the controls;
- Static positioning: accurate;
- Dynamic positioning: accurate;
- Consumed electrical power: low;
- The servosystem operates without any noise and vibrations;
- The servosystem can be designed in a compact construction;
- High reliability.

The DC direct-drive construction torque motor is equivalent to a DC servomotor with a gear or mechanical multiplier but, because of the latter's absence (gear / mechanical multiplier), the servosystem is ideal for very fast accelerations or decelerations. The lack of the gear in the system eliminates the errors caused by the frictions, the clearances among the gear sides and other mechanical accuracy errors, determines a very high positioning sensitivity-arc seconds. This positioning sensitivity firstly depends on the transducer detection accuracy-feed-back (synchro, resolver, encoder) which is directly coupled onto the load shaft.

The DC torque motor offers a perfect linearity $M = f(\omega)$, in relation to the AC two-phase servomotor (Fig.1) due to the fact that the frictions are constant compared to those of the other one, where they are variable function the speed and the control voltage. The performance of the DC torque motor can be estimated accurately enough by using the linearity conventional hypotheses of the servosystem. Thus, the servosystem time mechanical constant has the same magnitude order (milliseconds) as that of an AC servomotor. In any case, the effective time constants of the AC low power servomotors for low positioning speeds are twice up to five times smaller in comparison with the catalogue values. In this case, the higher values are determining factors for the establishing of the system stability. On the other hand, the time electric constant of a DC torque motor is very small (fractions of milliseconds). In a system with performances of the 2nd order, the time electric constant is that which determines the system stability. Due to the linear characteristics of the DC torque motor, they are recommended for being used in the servosystems requesting a position tracking accuracy within the speed range from several thousandes up to one. The dynamic regime is about ten times faster than that of the AC servomotor.

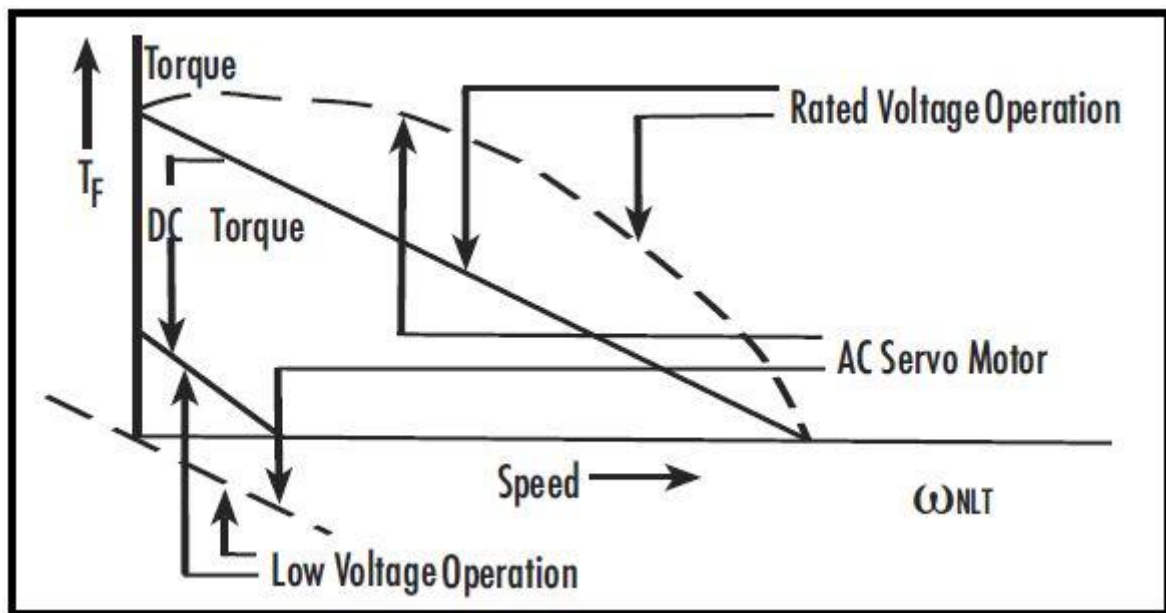


Fig.1 Torque-Speed characteristic of the DC torque motor compared to that of the AC servomotor.

2. Operating equations.

The DC torque motor has a construction similar to that of a DC classic motor, consequently there can be used its operating equations

$$U = E + IR_M \quad (2.1)$$

$$E = K_E \omega \quad (2.2)$$

$$T = K_T I \quad (2.3)$$

where:

U – supply voltage [V];

E – back electromotive force (back EMF) [V];
 R_M (R) – DC resistance of the rotor winding [Ω];
 T - torque [Nm];
 ω – rotation angular speed rad/sec];
 K_T - torque constant;
 K_E (K_B) – back EMF constant;

If in equation (2.1) there are introduced equations (2.2) and (2.3), there results:

$$U = K_E \omega + \frac{T \cdot R}{K_T} \quad (2.4)$$

where: the first term of equation (2.4) represents the part of the supply voltage necessary to produce the motor back EMF at the requested speed and the 2nd term represents the part of the supply voltage necessary to produce requested torque.

The torque motors can satisfactorily operate practically at any level of supply voltage without the essential change of the mechanical characteristics: the power, torques, and electro-mechanical constants remain unchanged. Fig.2 shows the equivalent diagram of the torque motor.

where: the $\frac{L}{R}$ ratio represents the time electric constant. The L component stands for the armature inductivity and can be minimized through an adequate design of the magnetic circuit.

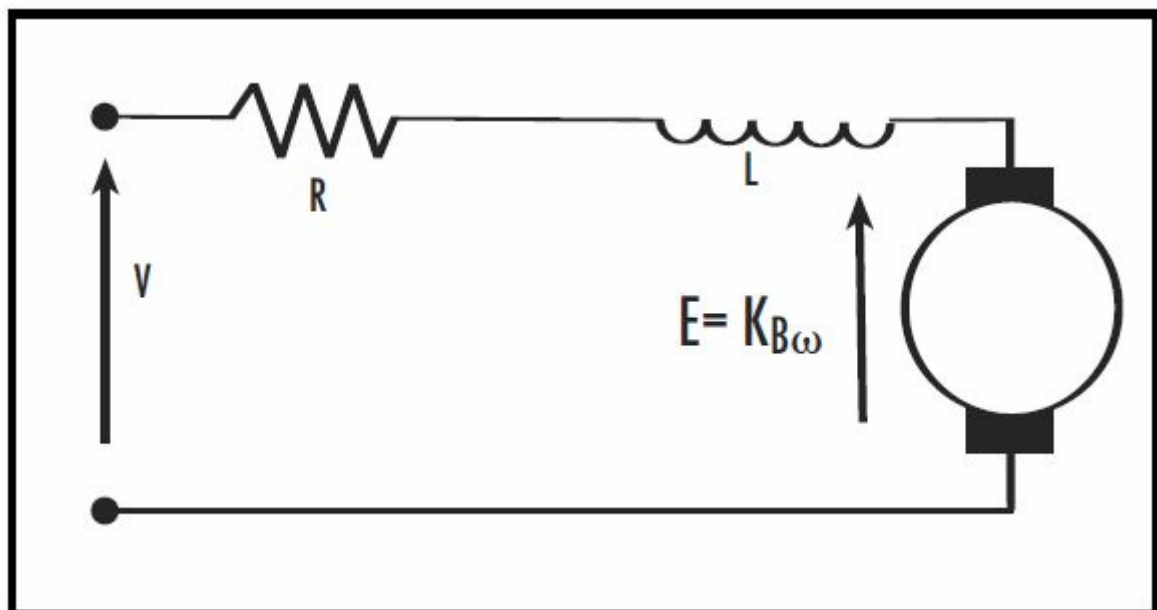


Fig.2 Equivalent circuit of DC brushed motor

Energy relations.

If equation (2.1) is multiplied by the absorbed current I , then there results the power balance:

$$UI = EI + RI^2 \quad (2.5)$$

The first term of equation (2.5) represents the absorbed power, the second term (EI) stands for the mechanical power (W) developed in the motor shaft which includes the friction and iron losses, the third term represents the copper losses. The mechanical power developed in the motor shaft results from equation (2.6):

$$EI = \frac{T \cdot \omega}{0.007062} \quad (2.6)$$

Under short – circuit conditions, equation (2.6) becomes:

$$P_p = \frac{T_p \cdot \omega_0}{0.007062} \quad (2.7)$$

where: ω_0 is the no-load theoretical speed (without the losses effect).

Heat considerations: the absorbed winding electrical power is changed into mechanical power developed by the rotor on one hand, as well as into calorific power dissipated in the winding, on the other hand. For this reason, the user must have in view that the motor overtemperature should not exceed its insulation class and, at the same time, the operating critical temperature of the magnets which, generally, are made of rare earths.

3. Construction.

From a constructive viewpoint, one distinguishes two types of DC torque motors: torque motors with and without commutator.

3.1. Torque motors without commutator. These consist of two armatures:

- stator, made up of stamped and glued laminations, equipped with a ring type winding; because of this construction, the cogging torque is null;
- rotor provided with permanent magnets. Figure 3.1.1 shows the construction of this type of torque motor.

This construction limits the domain of the rotor rotation movement which is function the number of the rotor pole pairs; consequently these motors are called limited angle torque motors. Figure 3.1.2 shows the mechanical feature corresponding to a four-pole construction.

3.2 Torque motors with commutator. Unlike the first type, these motors have a reversed construction – the stator is equipped with permanent magnets and the rotor is similar to that of a DC classic motor (Fig.3.2).



Fig. 3.1.1

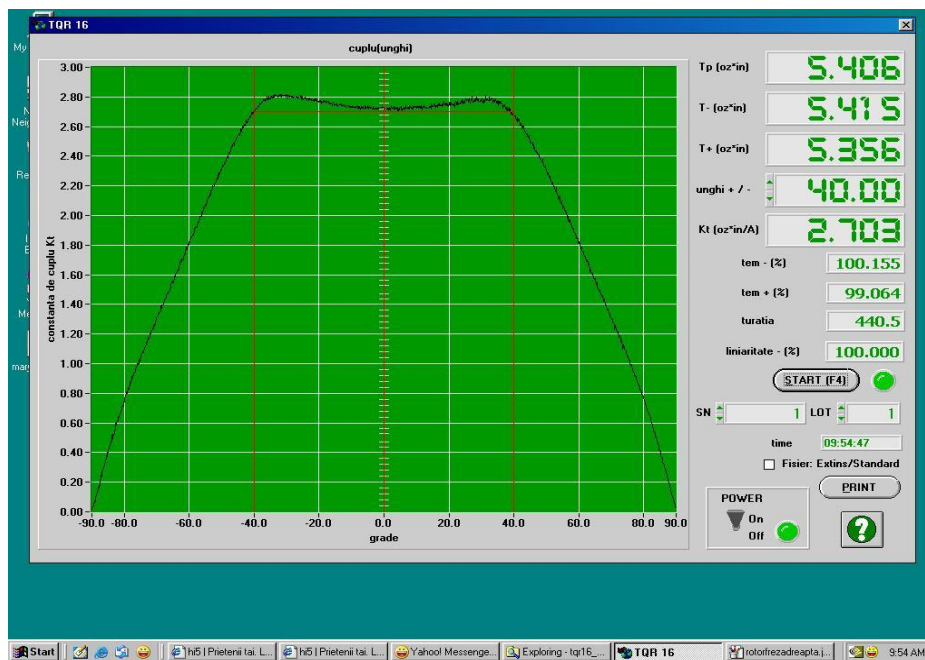


Fig.3.1.2

The rotor lamination stack is made up slot, stamped and glued laminations within which a DC winding is distributed and connected to the commutator.

As far as the commutator is concerned, it can have a classic construction if the length – outside diameter ratio is overunity and if this ratio is underunity, ICPE SA Department 4 has developed a technology enabling the attachment of the commutator directly to the front side of the winding. The brush block assembly with the commutator brushes is carried

out in a detachable construction and it is operational by being attached to the stator housing by the user – it is delivered separately.

The commutator brushes are of the silver-graphite type and the springs which are made from bronze-beryllium also represents the paths of current.

With the two types of torque motors, ICPE SA Department 4 uses, for the achievement of the armatures with permanent magnets, the SPM-type technology (surface mounted permanent magnet); on demand, there can also be used IPM technology (inside mounted permanent magnet).



Fig. 3.2

4. Definition of the electromechanical parameters.

4.1. Torque motors without commutator.

Peak torque T_p [N.m]

This electromagnetic torque is obtained under short-circuit conditions, at a current I_p , in the reference position of the rotor: $\alpha = 0^\circ$ (Fig.3.1.2);

Angular range α [deg]

This is the angular operating range;

Power P_p [W]

This is the power absorbed at the peak torque; computed value: $R_M I_p^2$;

Motor constant K_M [$\frac{N.m}{\sqrt{W}}$]; this is the value computed by: $\frac{T_p}{\sqrt{P_p}}$

The supply voltage U_p [V]

This is the voltage required to obtain current I_p with the winding at 25°C;

Peak current I_p [A]

This is the motor current consumption required to obtain the peak torque with the winding at 25°C;

Maximum current I_{max} [A]



This is the value given for the metal permanent magnet type motors below which there is no risk of demagnetization;

Resistance R_M [Ω]

This is the resistance viewed from the motor output leads measured at 25°C;

Torque constant K_T [$\frac{N.m}{A}$]

The electromagnetic torque at $0.25I_p$ (or at another value mentioned in the specification) divided by the current value;

Back EMF constant K_E [V/rad/s]

This is the induced voltage/speed ratio when the motor is driven at 1000 rev/min (or at another value mentioned in the specification);

Time electrical constant τ_e [ms]

With the rotor locked, this is the time taken by the current to reach 63% of the value $\frac{U}{M_M}$, where U is the voltage required to obtain $0.25I_p$;

Time mechanical constant τ_m [ms]

This is the value computed by using the equation: $\tau_m = \frac{J_m \cdot R_M}{K_T \cdot K_E}$

Static friction torque T_F [cN.m]

This is the motor dry friction torque (mainly of magnetic origin)

Viscous damping coefficient F_0 [N.m/rad/s]

This is the value computed by using the equation: $F_0 = \frac{K_T \cdot K_E}{R_M}$;

Heat constant T_T [°C/W]

This is the winding temperature rise versus the motor dissipated power. This value is measured on a thermally insulated motor in calm atmosphere.;

The winding maximum temperature $\Delta\theta$ [°C]

This value depends on the insulation class of the magnet wire and the electro-insulating materials;

Rotor inertia J_m [g.cm²]

This is the measured inertia for the motor rotating armature;

Maximum theoretical acceleration a [rad/s²]

This is the value computed by using the equation: $a = \frac{T_p}{J_m}$.

4.2 Torque motors with commutator

Peak torque T_p [N.m]

This electromagnetic torque is obtained under short-circuit conditions, at a current I_p . This is the average of the torque values measured in both directions of rotation and in both directions of power supply;

Power at peak torque P_p [W]

Absorbed power corresponding to the peak torque;



Motor constant K_M [$\frac{N.m}{\sqrt{W}}$]; this is the value computed by: $\frac{T_P}{\sqrt{P_P}}$

Electrical time constant τ_e [ms]

With the rotor locked, this is the time taken by the current to reach 63% of the value $\frac{U}{M_M}$, where U is the voltage required to obtain $0.25I_P$;

Time mechanical constant τ_m [ms]

This is the value computed using the equation: $\tau_m = \frac{J_m \cdot R_M}{K_T \cdot K_E}$;

Static friction torque T_F [N.m]

Average of the friction torque values measured on a motor which is not energized and is driven at a very low speed (a few rev/min)

Viscous damping coefficient F_0 [N.m/rad/s]

This is the value computed by using the equation: $F_0 = \frac{K_T \cdot K_E}{R_M}$;

Ripple torque T_R [%]

This is the value computed by using the equation: $T_R = 100 \frac{T_{\max} - T_{\min}}{T_{\max} + T_{\min}}$, at

a current of $0.25I_P$ or at another value mentioned in the specification;

Heat constant T_T [°C/W]

This is the winding temperature rise versus the motor dissipated power. This value is measured on a thermally insulated motor in calm atmosphere;

The winding maximum temperature $\Delta\theta$ [°C]

This value depends on the insulation class of the magnet wire and the electro-insulating materials;

Rotor inertia J_m [kg.m²]

This is the measured inertia for the motor rotating armature;

Maximum no-load speed ω_{NL} [rad/s]

This is the value computed by using the equation: $\omega_{NL} = U_P / K_E$;

The supply voltage U_P [V]

This is the voltage required to obtain the current I_P with the winding at 25°C;

Peak current I_P [A]

This is the motor current consumption required to obtain the peak torque with the winding at 25°C;

Resistance R_M [Ω]

This is the resistance viewed from the motor output leads measured at 25°C;

Torque constant K_T [$\frac{N.m}{A}$]

The electromagnetic torque at $0.25I_P$ (or at another value mentioned in the specification) divided by the current value;

Back EMF constant K_E [V/rad/s]



This is the induced voltage/speed ratio when the motor is driven at 80% of the maximum no-load speed;

Inductance L_M [mH]

This is the value computed by using the equation: $L_M = \frac{e}{\omega} \cdot R_M$.