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Why choose a D.C. motor?

Many applications require a high starting torque. The D.C. motor, by its very nature, has a high torque vs. speed characteristic, enabling it to deal with high resistive torques and absorb sudden rises in load effortlessly; the motor speed adapts to the load. In addition, D.C. motors are an ideal way of achieving the miniaturisation that is so desirable to designers, since they offer a high efficiency as compared with other technologies.

How to choose from the Crouzet range

The motor is chosen on the basis of the usable power that is required.
A direct drive motor or a geared motor can be chosen, depending on the required speed.

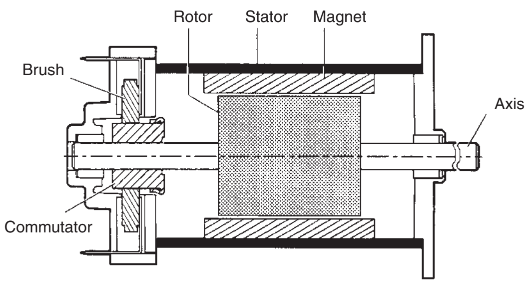
Speeds from 1000 to 5000 rpm ⟶ Direct drive motor
Speeds below 500 rpm ⟶ Geared motor

The gearbox is chosen on the basis of the maximum recommended torque in the steady state.

Definition of a D.C. motor

This motor is characterised by linear operating principles.
These principles make the features of the motor easier to use than those of synchronous or asynchronous motors.

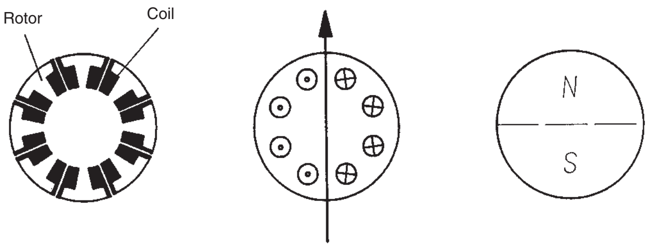
➜ Composition of a D.C. motor



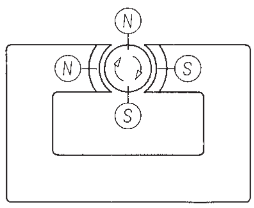
The stator consists of a metal housing and one or more magnets creating a magnetic field inside the stator. At the rear of the stator are the brush holders and the brushes, which provide the electrical contacts with the rotor.
The rotor itself consists of a metal housing with coils which are interconnected at the commutator.
The commutator/brush unit is used to select all the coils through which current will pass in one direction and all the coils through which current will pass in the other direction.

Operating principle

No matter how complex the winding is, once it is supplied with power it can be represented as a ferromagnetic cylinder with a solenoid at its edge.
The wire of this solenoid is made up of the bundle of wire located in each slot of the rotor. The rotor then acts as an electromagnet. The direction of its magnetic induction is the axis separating the wires of the solenoid according to the direction of the current passing through them.



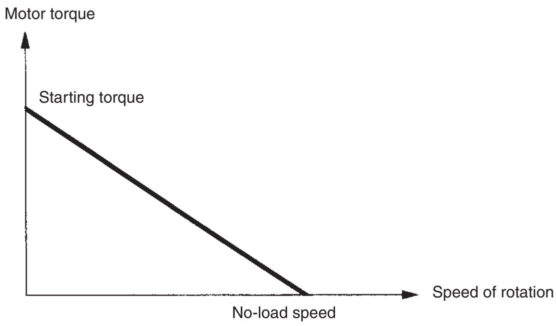
Therefore the motor consists of fixed magnets, a moving magnet (the rotor) and a metal housing to concentrate the flux.



Attraction of the unlike poles and repulsion of the like poles generates a torque which is applied to the rotor, causing it to turn. This torque is at its maximum when the axis of the rotor poles is perpendicular to the axis of the stator poles.
When the rotor starts to turn, the brushes change commutator segments.
The coils are supplied with different supply voltages, so the axis of the new rotor poles is still perpendicular to that of the stator. Thanks to the action of the commutator, the rotor never stops turning, no matter what its position. The resulting torque ripple decreases as the number of commutator segments increases.
Switching round the power supply leads in the motor reverses the current in the rotor coils and hence the north and south poles. The torque is then applied in the opposite direction from before. The motor changes its direction of rotation. By its very nature, the D.C. motor is a reversible motor.

➜ Torque and speed of rotation

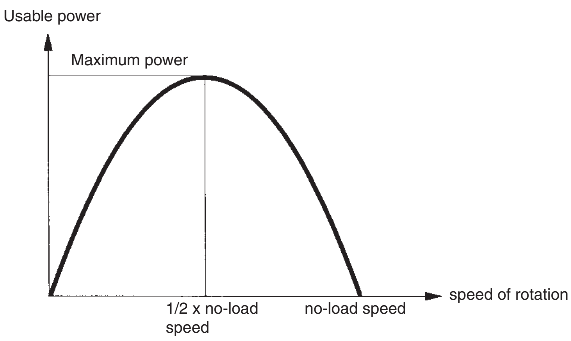
The torque delivered by the motor and its speed of rotation are mutually dependent.
This is a fundamental characteristic of the motor. This is a linear relation which determines the no-load speed and the starting torque of the motor.



The torque/speed curve can be used to determine the usable power curve for the motor.

$$Pu\ (W) = \frac{2\pi}{60} \times C\ (N.m) \times N\ (rpm)$$

Usable power — Motor torque — Speed of rotation



The torque/speed and usable power curves are dependent on the supply voltage to the motor.
The supply voltage given for the motor corresponds to continuous use of the motor at an ambient temperature of 20°C at the nominal operating point.

It is perfectly possible for the motor to be supplied with a different voltage (generally between -50% and +100% of the intended motor voltage).
If it is supplied at a lower voltage, the motor will be less powerful.
If it is supplied at a higher voltage, it will be more powerful but will heat up more (for intermittent operation).

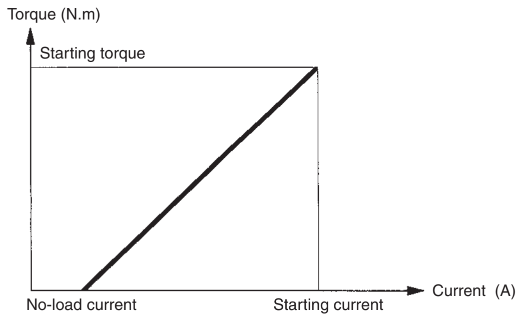
For variations in supply voltage of around -25% to +50%, the new torque/speed curve is parallel to the old one. The starting torque and the no-load speed vary by the same percentage (n%) as the supply voltage. The maximum usable speed of the motor has to be multiplied by $(1 + n\%)^2$.

Example: For a supply voltage greater than 20%

- ➛ Starting torque above 20% (x 1.2)
- ➛ No-load speed above 20% (x 1.2)
- ➛ Usable power above 44% (x 1.44)

➜ Torque and supply current

This is the second important characteristic of the D.C. motor. It is a linear relation and can be used to determine the no-load current and the locked-rotor current (starting current).



This curve is not dependent on the motor supply voltage. The end of the curve simply lengthens to a greater or lesser degree depending on the torque and the starting current.
The gradient of this curve is known as the "torque constant".

$$Kc = \frac{Cd}{Id - Io}$$

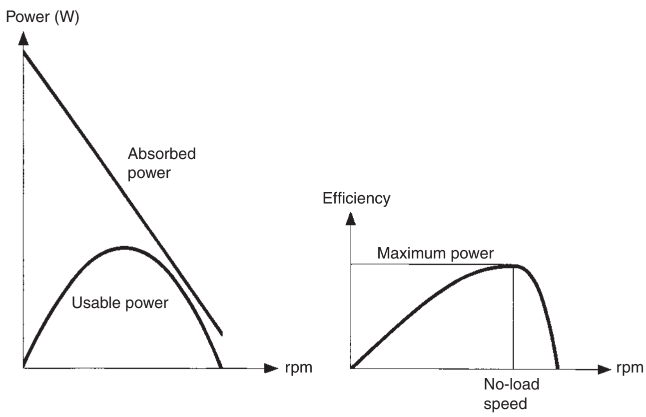
This torque constant is such that:

$$C = Kc\ (I - Io)$$

Kc Io is known as the "rotational friction torque".
The torque is then expressed as follows:

$$C = Kc\ I - Cf \quad \text{where} \quad Cf = Kc\ Io$$

Kc = Torque constant (Nm/A)
C = Torque (Nm)
Cd = Starting torque (Nm)
Cf = Rotational friction torque (Nm)
I = Current (A)
Io = No-load current (A)
Id = Starting current (A)



The torque/current and torque/speed curve can be used to derive the curve for the power consumption as a function of the speed of rotation of the motor.

➜ Efficiency

The efficiency of a motor is the ratio between the usable mechanical power that it can deliver and the electrical power that it absorbs. Since the usable power and the absorbed power vary differently with the speed of rotation, the efficiency also depends on the motor speed. The efficiency is at its maximum at a given speed of rotation that is greater than half the no-load speed.

➜ Temperature rise

The temperature of a motor rises owing to the difference between the absorbed power and the usable power of the motor. This difference represents the motor losses.
The temperature rise is also associated with the difficulty experienced by the motor losses in propagating from the rotor to ambient air (thermal resistance). The thermal resistance of the motor can be reduced significantly by encouraging the transfer of heat by mounting it on a support with improved thermal conductivity.

Important

The nominal operating characteristics correspond to the voltage/torque/speed characteristics which allow continuous operation at an ambient temperature of 20°C.
Above these operating conditions only intermittent duty cycles will be possible: without exception, where extreme conditions prevail, all checks should be performed in the real-life context of the customer application to ensure safe operation.

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Combining a motor + gearbox

D.C. motors are built to operate in the steady state in a speed range close to their no-load speed. This speed range is generally too high for most applications. In order to reduce this speed we offer users a complete range of geared motors, each with a series of gear ratios. Together they can be used to implement a wide variety of functions.

➜ Characteristics of a gearbox

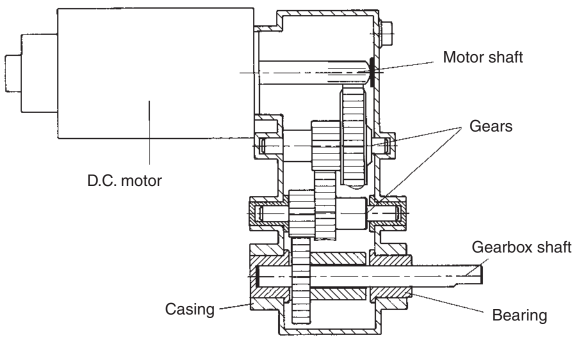
Each gearbox has been designed for a certain task. We have defined its possibilities and its limitations for an optimum service life.

Its principal characteristic defines its ability to withstand **a maximum torque in the steady state**.

The range of gearboxes contained in this catalogue can withstand maximum torque values of **0.5 to 6 N.m** over a long service life. The values shown are for standard products in specified normal operating conditions.
In some cases the values can be increased if a shorter service life is required.
All such special cases must be handled by the design office.

Every gearbox does have one limit, however, which is the **breaking torque.**
Applying this torque to the gearbox may result in its immediate destruction.

➜ Construction of a gearbox



➜ Choosing a geared motor

This choice is governed by the usable power to be output by the geared motor.

$$P_{usable} = \frac{2\pi}{60} . C . N$$

W — Nm — rpm

The usable power of the geared motor must be greater than or equal to the desired usable power. The appropriate choice can be made simply by checking that the operating point (torque and output speed of the geared motor) is below the nominal torque/speed curve of the geared motor. The desired gearbox output torque must be compatible with its maximum recommended torque in the steady state.

➜ Choosing the gear ratio

Two selection criteria can be used.

- The first criteria only involves the desired gearbox output speed. It is suitable for most common applications and its simplicity justifies its use.

$$R = \frac{N1}{Nb}$$

N1 = desired speed of geared motor
Nb = base motor speed

- The second selection criteria involves the desired usable power output by the motor. The speed of rotation of the motor is determined by:

$$N = 1/2 \left(No + \sqrt{No^2 - \frac{4P}{A}}\right) \text{ where } A \ \frac{\pi Cd}{30No}$$

N = speed of motor (rpm)
No = no-load speed of motor (rpm)
P = desired usable power (W)
Cd = starting torque of motor (Nm)

This gives: $R = \frac{N1}{N}$

To avoid having to work with numbers below 1, it is customary to use the number 1/R when referring to the gear ratio of a gearbox. The fact that this is a reduction gearbox and not a step-up gearbox eliminates any ambiguity about the meaning of the number used.

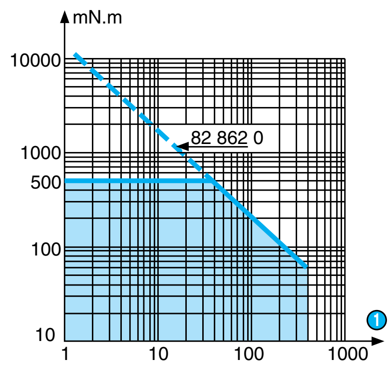
$$1/R = \frac{Nb}{N1} \quad \text{or} \quad 1/R = \frac{N}{N1}$$

➜ Geared motor curve

The zone shown in blue represents the operating range of the geared motor.

The horizontal line marks the maximum torque available in the steady state for the gearbox service life shown in the catalogue.

For lower torque ratings, the service life of the gearbox will be increased. For higher torque ratings, it will be reduced.



1 Speed in rpm

Design of Crouzet D.C. motors

➜ Safety

Crouzet D.C. motors are designed and manufactured to be integrated into appliances or machines which meet, for example, the specifications of the machine standard:
EN 60335-1 (IEC 335-1, "Safety of household and similar electrical appliances").
The integration of Crouzet D.C. motors into appliances or machines should generally take account of the following motor characteristics:

- no earth connection
- "simple isolation" motors
- protection index: IP00 to IP40
- insulation system class: A to F

} (see detailed characteristics on the catalogue page for each type of motor)

EUROPEAN LOW VOLTAGE DIRECTIVE 73/23/EEC OF 19.02.73
CROUZET D.C. motors and geared motors are outside the scope of this directive (LVD 73/23/EEC applies to voltages over 75 volts D.C.).

➜ Electromagnetic compatibility (EMC)

On request, Crouzet Automatismes will provide the EMC characteristics of the various types of product.

EUROPEAN DIRECTIVE 89/336/EEC OF 03/05/89, "ELECTROMAGNETIC COMPATIBILITY":

D.C. motors and geared motors which are components designed for professionals to be incorporated in more complex devices, and not for end users, are not covered by this directive because they are outside its scope.