Selecting a dc micromotor

General sizing procedures

There are several things to consider when sizing dc motors. The main constraint on motor operation, though, is temperature. The primary source of heat in a dc motor is the power dissipated in the coil through copper losses. To calculate power dissipation, use the following formula:

$$P = I^2 x R$$

where:

P = dissipated power, W; I = armature current, A; and R = armature resistance, Ohms.

To find current through the motor, divide the torque requirements by the motor's torque constant.

$$I = \frac{T}{K_t}$$

where: T = torque requirement, oz-in.; and K_t = motor torque constant, oz-in./A.

Using the thermal resistance specification for the motor coil to ambient, the steady state temperature rise can be found using the following formula:

$$\Delta t = P x R_{th}$$

where: Δt = temperature rise from external ambient to the motor coil; P = power dissipated in the coil; and R_{th} = thermal resistance from coil to ambient.

The temperature of the coil is determined by adding the rise in temperature (Δt) to the motor's ambient temperature. This value can then be compared to the maximum permissible temperature.

Dc motors usually reach their maximum output at half the no-load speed and half the stall torque. However, most motors won't operate at maximum output because of temperature limitations. When operated with a constant current, dc motors produce constant torque regardless of the speed. For dc motors operated at a constant voltage, the speed and torque produced are inversely related. The higher the torque, the lower the speed of the motor.

Their most efficient operating point for a dc motor is generally defined as 90% of no-load speed and between 10 and 30% of stall torque. The maximum efficiency of permanent magnet dc motors is typically reached when the motor operates around 10% of its stall torque. If an application requires high efficiency, a motor with a stall torque approximately ten times the required torque needed for operation will work best.

Efficiency is given by the ratio of mechanical power out to electrical power in expressed as a percentage:

$$\eta = \frac{P_o}{P_{in}} x100\%$$

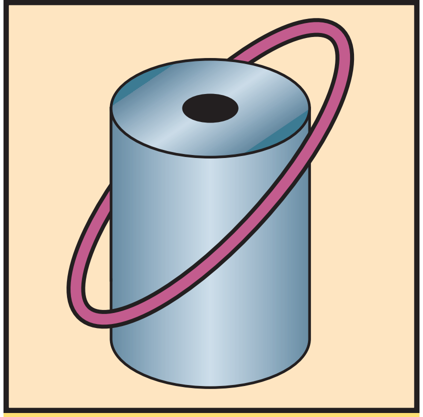
When using dc micromotors with gearing, the selection criterion is minimum practical speed. It's best to choose a motor with higher voltage ratings than the available voltage supply. The motor will run more quietly and last longer. Using preloaded ball bearings and precious metal brushes can also reduce the audible noise.

Types of dc motors

There are several types of wound-field dc motors, usually characterized by the electrical connections between the stator windings and armature. Shunt-wound motor windings are connected in parallel with the armature. In series-wound designs, they are connected in series with the armature. A compound motor has one stator winding in series and one in parallel with the armature.

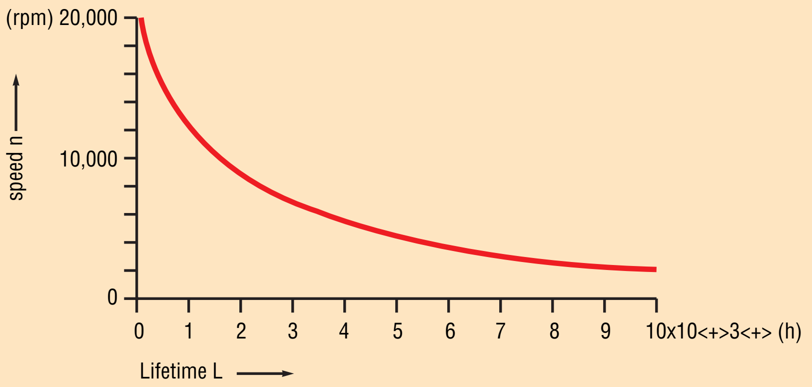
Where motor armatures are built us-

Around and around

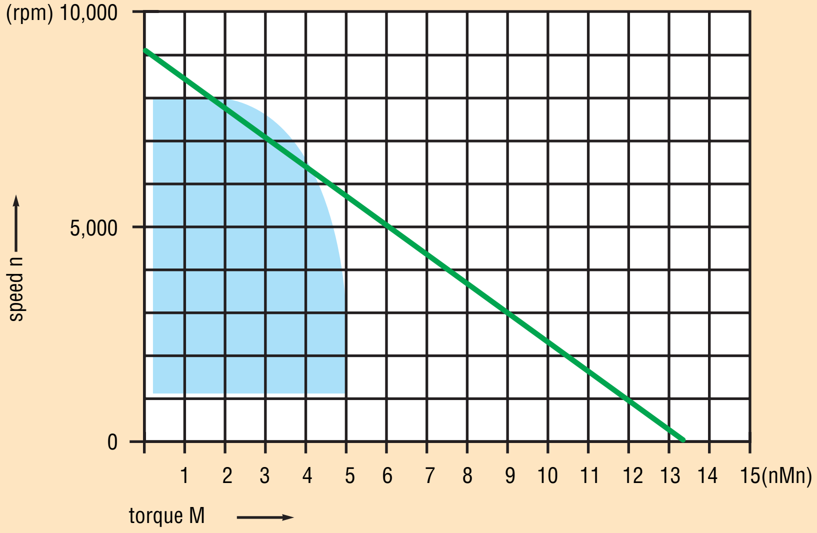


In coreless motors, coils are wound around a mandrel. The windings have no heads that add electrical resistance and mass to the coil without contributing to torque production. In addition, the windings are skew wound to reduce cogging and torque ripple. Even though the illustration shows the coil as a circular structure, in practice, coil taps are taken off at the commutator end of the armature to switch current into the coil windings at appropriate times.

The long and short of life



Speed as a function of lifetime



Area of operation for long lifetime (shaded)

These charts tell the story of expected service life. Limiting motor operation to the shaded portion of the torque-speed curve will maximize motor life.

ing stacks of laminations, the magnets must be located outside the outer diameter of the armature. Instead of pole shoes with magnet wire wound around them, permanent magnets are installed inside the motor case.

Small motors often require an alternative design that uses a "coreless" armature winding. These armatures depend on the coil wire itself for structural integrity and have no iron. As a result, the armatures are hollow, and the permanent magnet can be mounted inside the coil, allowing smaller and lighter motors with excellent dynamic characteristics.

This winding construction reduces armature inertia considerably, as well as armature inductance. When it comes to EMI noise, coreless dc motors have a lower armature inductance than comparably sized iron-core motors.

There are drawbacks, though. Lack of iron in the armature reduces the thermal capacity of the motor significantly. Thermal time constants are much shorter than would be expected for iron-core motors with similar power capacity. Also, coreless armatures are not as structurally sound as configurations with iron laminations. Thus, there's a physical limit on motor size.

Cost savings

Precious metal brush-commutator systems are generally used in small motors where the size of graphite-based brushes would prohibit their use. Since the voltage drop between brushes and commutator is generally small in precious metal systems, motors can be made to operate at low voltages.

Bearings provide mechanical support for the armature assembly and allow it to rotate freely in the motor's magnetic field. The most common types of bearings are ball and sintered metal.

Ball bearings are used in applications where relatively large radial or axial shaft loads exist. They are almost always a standard feature in motors with power capacities of 5 W or greater because, as motor size increases, even a slightly imbalanced rotating armature develops enough radial forces to reduce bearing life.

Sintered metal bearings are an economical choice in small motors where shaft loads are minimal. They are almost always used in applications involving a small motor and a gearhead, but usually not in situations where rotational speed is very low.

There must be a lubrication film between the shaft and bearing, usually developed in a process called hydro-dynamic lubrication. But it's often difficult to establish and maintain this film at slow speeds. In applications involving temperature extremes or vacuum, be sure to consult with the motor manufacturer on the best lubricant to use.

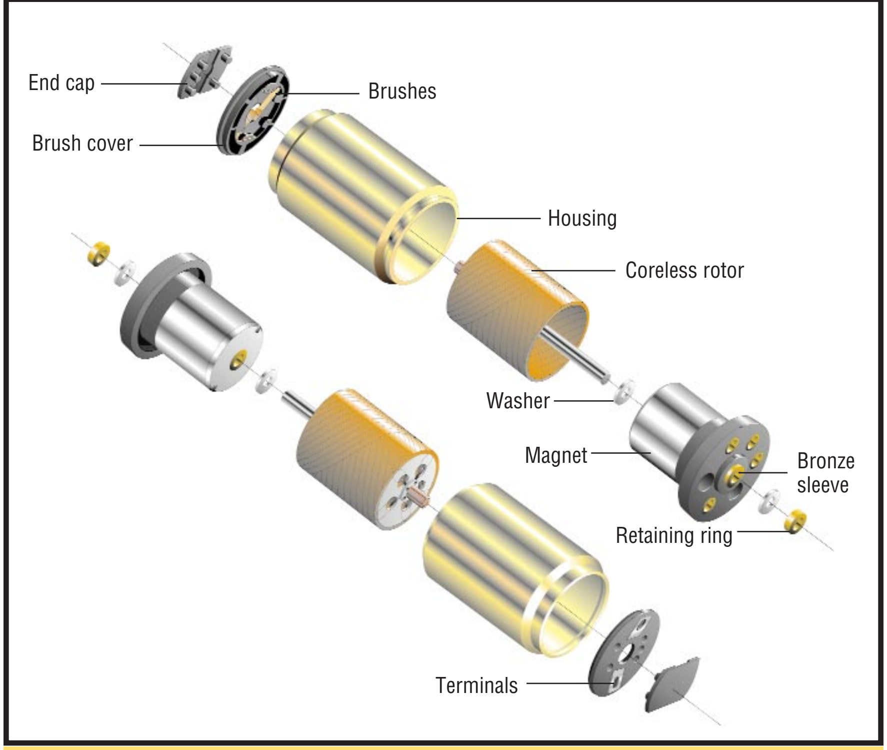
To a longer life

Motor service life primarily depends on the torque and speed demands of an application. As torque increases, so does current through the armature. This increases current density at the brush-commutator interface, which erodes brush and commutator material, limiting service life. High rotational speeds also shorten motor service life by accelerating mechanical wear. Motors with graphite on copper commutation systems should be run continuously at no more than one-half rated stall torque.

One technique used to increase motor service life is to include a capacitor disk mounted to the commutator. Each winding is connected in parallel with a small capacitor. As the magnetic field collapses after commutation, it charges the capacitor rather than creating an arc between brush and commutator.

Frequent starting and stopping or re-

Parts to the whole



A look inside

versals of direction can also stress a motor. Both situations result in periods of high current density. Other factors to watch include:

- warm or dry conditions that hasten the breakdown of bearing and commutator lubricants.
- cold conditions, which increase the viscosity of lubricants, causing the motor to run at a higher current.
- shock loads and vibration, which contribute to the tendency of brushes to bounce on the commutator, as well as accelerate bearing wear.

The beginning of coreless

Early in the 1950's, applications began to require small, efficient dc motors capable of high angular acceleration and that were appropriate for battery powered operation. Iron-core motors had drawbacks, including their intrinsic high armature inertia and electrical inductance.

To meet this new need, Dr. Fritz Faulhaber developed a technique for producing motors that did not require the use of iron laminations in the armature. This motor type became known as coreless or ironless core.

Standards and regulations

The preeminent standards source for traditional motors has been the NEMA publication MG-1. A more recent addition is NEMA standard MG-7 for control motors and related devices. This standard is currently under revision. Other standards include ANSI and IEC for rotating machinery. Plus, there are IEEE standards for motor-related test procedures; and product and interface standards, which are typically niche and application specific.

With the emergence of networked and integrated motor and control systems, engineers also need to be aware of various computer and hardware platforms, software programming conventions and options, and an emerging body of safety standards that may effect usage and installation considerations.

An area that may grow in importance is that of environmental and reuse and recovery standards. There is already a considerable movement under way to explore the banning of lead, cadmium, mercury, and other elements which are important in the function and performance level of motors and motor-related products. These regulations are already affecting packaging, installation guidelines, and usage constraints in Europe.

Size design considerations

The biggest enemy of small motors is heat (I^2 x R losses). In application, it is frequently necessary to make sure motors are properly installed to allow maximum ventilation. Sink as much heat as possible, or add forced air for cooling. Also pay close attention to the motor's thermal limits to keep them from burning up. Miniature motors typically rotate at much higher speeds than their larger counterparts, so their lifetimes are usually shorter.

Failure modes

Motor failures usually come about from electrical or mechanical malfunctions. In the case of electrical failures, improperly insulated or constructed motors sometimes fail from short circuits. They can also fail from running excessive levels of current (heat) through the motor wiring and communication systems.

For brush type motors, commutation failure is the usual suspect, either due to the wearing out of the brushes or physical contamination of the armature, which can also lead to electrical shorts. For brushless motors, the typical problem is bearing failure. This is why brushless motors are rated for life according to the bearing quality. Barring unforeseen problems, ball bearing motors last longer than those using sintered bearings. Ceramic bearings also are very good for extending gearmotor life; however, rotational speed usually has to be relatively slow to prevent shaft erosion in the case of Al_2O_3 formulations. SiN is a bearing material in some specialty applications, but it is a relatively expensive choice.

Also keep in mind the effects of vibration, shaft alignment, ambient temperature, and environmental factors such as wash-down, exposure to elements, or proximity to corrosive processes. ●

This month's handy tips are courtesy of MicroMo Electronics Inc., Clearwater, Fla.

Next step...

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