Brush or brushless motors?

Brush motors are generally less expensive than brushless versions and are more easily controlled with less complex electronics. The lower motor is fitted with a 64:1 gear head.

Each has advantages. But regardless of which off-the-shelf motor you choose, expect to modify it to meet the specs.

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Selecting dc motors for medical equipment often starts with off-the-shelf designs. The details of the application will then steer the selection more toward a brush-commutated or brushless dc design.

Some medical devices, such as surgical tools and drills, need motor speeds over 10,000 rpm. Others, such as imaging and treatment tables, may need low noise and low vibration mostly to help quell patient anxiety and stress, but also to provide more pleasant working conditions for medical staff. To make the right selection, it helps to know how permanent magnet (PM) brush-commutated and brushless dc servo motors compare.

Words to the wise

Regardless of whether a motor is brush or brushless, some medical device specifications come with frequently encountered wording that impact either motor's design. For example, a requirement for autoclavability can mean encapsulating motor windings in potting compounds, coating printed circuit boards, using specific greases for bearing lubrication, shielding magnets with specialized platings or coatings, using corrosion resistant metals, and sealing the motors. To see how these requirements are most easily met, it's a good idea to take a closer look at how the motors stack up in terms of size, power density, speed, noise, and life expectancy.

Also, take generalizations with a grain of salt. This is true with any comparison of competing technologies. General motor characteristics may be typical, useful, and preliminarily necessary, but should never be considered absolute. For instance, there will always be exceptions to advantages or disadvantages, especially because motors can be engineered to overcome perceived deficiencies.

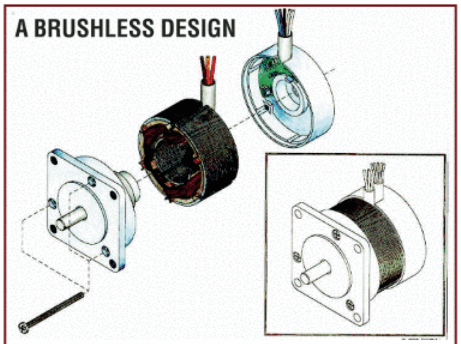
Consider these

All dc servo motors convert electrical energy into mechanical energy through two interacting magnetic fields. One field is produced by a permanent magnet assembly and the other by an electric current in the motor windings. The relationship between these fields and those of the wound armature (brush motors) or permanent-magnet rotor (brushless motors) generates a torque that turns the rotor. As the rotor turns, current in the windings is commutated, or switched, to produce continuous torque.

Conventional brush-commutated dc motors use brushes commonly made of graphite with some metal content. Brushless motors commutate electronically using a permanent-magnet rotor, wound stator, and rotor-position sensor. Each technology has pros and cons. For example:

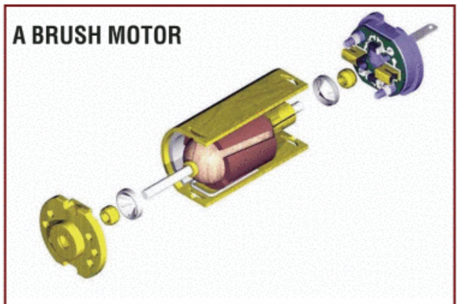
Relative physical size and power

A BRUSHLESS DESIGN



The sketch of a brushless motor shows the electronics necessary for commutation in the rear housing.

A BRUSH MOTOR



The 22-mm motor shows its brushes, the rectangular devices, in the cap to the upper right.

density is largely a function of where the wound field is located in the motor. Brush dc motors here have higher thermal impedance (windings on the armature or rotor) which creates a less efficient thermal path and lower rate of dissipation. Hence, to generate a particular continuous output torque, a brush motor may be larger than a brushless version. On the up side, a larger brush motor may not need the drive electronics necessary for brushless motors. On the downside, a larger motor may be a shortcoming for medical instruments that must be as small as possible.

The lower thermal impedance in brushless dc motors (windings are located in the stator) and a more efficient thermal path allows a higher heat-dissipation rate than brushed motors. Smaller brushless motors therefore, can generate as much or more continuous output torque as a brushed motor.

Speed can be tailored to the application. Brush-commutated dc motors should generally run over 1,000 rpm to keep particles from accumulating in slots between commutator segments, which could create shorts between commutator bars. Gearheads are often used to generate shaft speeds below 1,000 rpm. Operating speeds above 10,000 rpm are common to brushless motors and less so for brush versions.

High rotational speeds for brushless motors is often limited only by the mechanical integrity of the rotor, speed-related internal losses, and bearings. Speeds over 10,000 rpm are possible with appropriate designs.

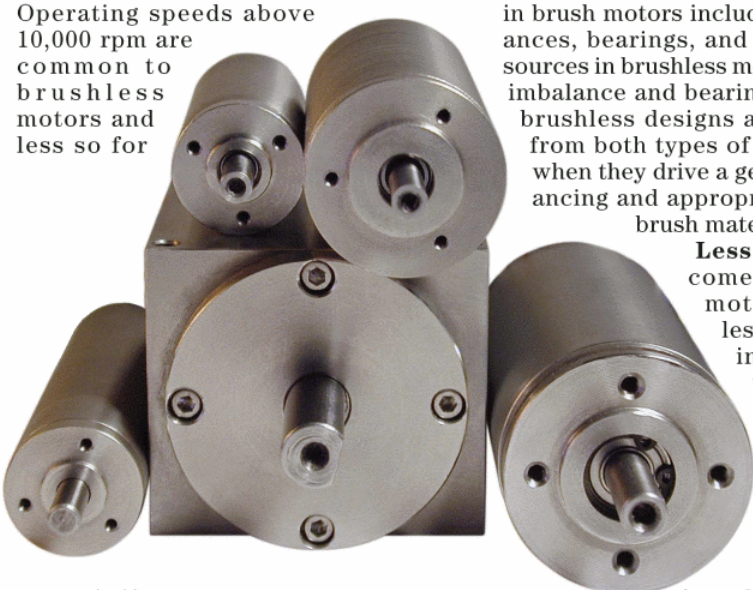
To find a motor's speed for particular conditions, use:

$$\omega = \frac{V - \left(\frac{T_l}{K_t} + I_0\right) R_t}{K_e} \times 1000$$

where ω = motor speed, rpm; V= supply voltage, V; T_l = load torque, oz-in.; K_t = motor torque constant, oz-in./A; I_0 = motor no-load current, A; R_t = motor terminal resistance, Ohms; K_e = motor voltage constant, V/1,000 rpm. When speed is known, you can solve this equation for one of the unknown quantities, often voltage or current.

Primary sources of audible noise in brush motors include armature imbalances, bearings, and brushes. Primary sources in brushless motors include rotor imbalance and bearings. But generally, brushless designs are quieter. Noise from both types of motors increases when they drive a gearhead. Rotor balancing and appropriate bearings and brush material reduce noise.

Less electrical noise comes from brushless motors and, in turn, less electromagnetic interference. Electrical noise may be hushed in brush



Brushless motors can turn at higher speeds than brush designs, over 10,000 rpm in some cases. They are also generally smaller, quieter, and generate more torque for a given diameter.

THE COMPARISON AT A GLANCE

Characteristic	Brush	Brushless
Speed	Runs best from 1,000 to 10,000 rpm	Capable of over 10,000 rpm
Torque		Generally higher for equivalent sizes but gearheads can adjust torque on either motor to the application
Noise		Generally lower
Cost	Generally lower	
Heat dissipation		Generally lower

motors by adding suppression devices and filters, or by the right brush materials.

Brushless motors generally operate longer than their brush-commutated counterparts. Life expectancy for brush motors is limited primarily by the life of the brushes, bearings, and gearbox. Life expectancies in the range of 2,000 to 5,000 hrs of operation are common, although actual service life varies greatly, depending on motor design and operating current, voltage, speed, and other conditions. Brushless motors often last over 10,000 hours and are limited by bearing life, radial, and axial loads, temperature, and environment.

Cost, always a consideration but not always a deciding factor, is generally lower for brush motors. Occasionally, they are up to half the cost of a brushless design. This makes them favorable in cost-sensitive consumer products.

These characteristics and others can serve as dc-motor-technology guideposts for designers. But there is more than technology to consider. For example, if the medical equipment requires FDA approval, it is important to partner with motor suppliers that have experience providing support in such approvals.

While FDA approval is not likely to affect motor selection, the manufacturer typically must be shown to have an established quality assurance system and be sensitive to the often complex qualification process. ■