

MEET YOUR SURGICAL DEVICE DESIGN GOALS WITH MINIATURE BRUSHLESS DC MOTORS

Considerations for selecting a mini motor technology solution to solve your surgical device design challenges

Background

Powered surgical hand tools are a mainstay of the operating room. For decades surgeons and device makers have relied on sterilizable Brushless Direct Current (BLDC) motors to meet the torque, speed, and reliability requirements of surgical hand tools. With the advance of surgical robotics and robotically assisted surgical devices, device makers continue to look to BLDC motors to meet their demanding requirements. Motors and motion are central to robotics, however the requirements for motors in surgical robotics differ somewhat from the typical requirements of both traditional robotics and traditional surgical hand tools.

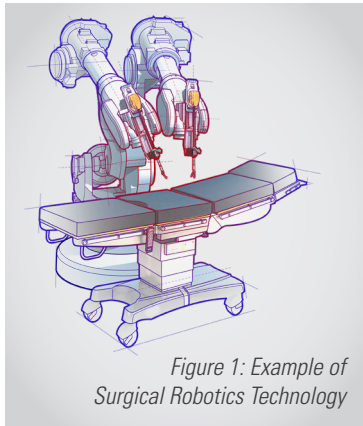


Figure 1: Example of Surgical Robotics Technology

Regardless of the nature of the device, surgeons need sterile tools they can depend on. They require devices that reliably and consistently function despite demanding field use and repeated steam sterilization during reprocessing.

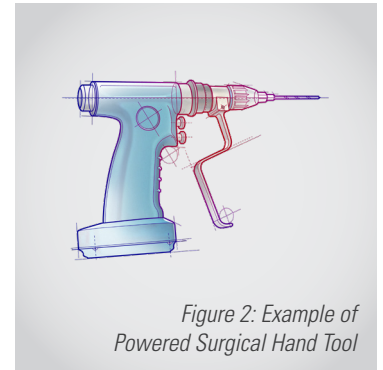


Figure 2: Example of Powered Surgical Hand Tool

Beyond the reliability requirements, surgical device designers have challenging motion problems to solve: exact speed and torque requirements, temperature and other constraints, or extreme position control demands. These device makers need motion control solutions that are ideally suited for their application, and which have been appropriately customized to both integrate with their tool and make the proper tradeoffs to optimize performance.

Methods to Maintain and Preserve the Sterile Field in the Operating Room

Infection, cross contamination, and the spread of disease are all important concerns in the operating room. Here are the most common approaches to protect the tool in the sterile field:

The Disposable Tool

One approach is for the hospital to utilize disposable, single-use tools. These generally use inexpensive motors (long life is not required) and plastic components. These tools must be disposed of after each surgery. While this approach simplifies reprocessing and eliminates the requirements of tool maintenance, it also requires a consistent supply of tools be maintained and increases the amount of hazardous waste produced by the hospital. In addition, disposable tools are typically not the most economical option when compared against the total life of a reusable tool.

Modular Design for Sterilization Using Non-Sterilizable Components

Another approach is to design the device such that exposed components are sterilized and others are not. For example, the BLDC motor

and accompanying controller and battery pack may be situated within the device, requiring the hospital staff to remove the motor/battery pack from the tool prior to sterilization. This approach requires that a special process is correctly followed to ensure the reprocessed tool is properly sterilized and may also require more durable electronic components and connections in the design due to repeated disconnection and reconnection of the motor and battery from the system.

Protective Barrier

Yet another approach is to cover the robotic arm or instrument with a (typically disposable) sterile barrier, e.g., plastic draping or a plastic “clamshell”. When successfully executed, the barrier well defines the sterile field and eliminates the need for components outside the field to be reprocessed. This approach is a typical design component for large surgical robotic systems – for which autoclave of the entire system is impractical. The ergonomic requirements of robotic systems also differ from traditional hand tool surgery – e.g., the motor may be physically located away from the surgical end effector and transmit motion via cable-drive, which may not be feasible for traditional surgery when a surgeon is trying to precisely manipulate a hand tool to perform a delicate task. Note this design approach is also typical for medical procedures that have less stringent sterilization requirements, such as dental and tattoo applications. There are down sides to this approach: complex draping schemes requiring systematic removal and replacement can significantly increase the time the operating room is engaged for a surgery. The draping is also often bulky and awkward, reducing visibility in the theater and negatively impacting ergonomics.

The Autoclavable Motor Solution

Finally – the device may be designed such that all components are sterilizable, including the motors. The introduction of sterilizable BLDC motors >30 years ago enabled tool designers to produce high power, ergonomic tools that could be trusted to be sterile due to the entire tool having gone through the sterilization process. The benefits carry over to robotically assisted surgical devices, which generally also require a sterile package with small size, high power, durability, efficiency, low noise, and long life.

Autoclavable BLDC Motor Design for Surgical Devices

Both traditional motorized hand tools and robotically assisted surgical devices can utilize BLDC technology in either a slotted or slotless configuration for a depiction of slotted vs slotless for so-called “in-runner” BLDC motors (where the rotor spins inside the stationary stator). Note that slotted vs slotless refers to the lamination type in the stator of the motor. Both technologies have their strengths – the requirements of the application will determine which technology is better suited for the motor design.

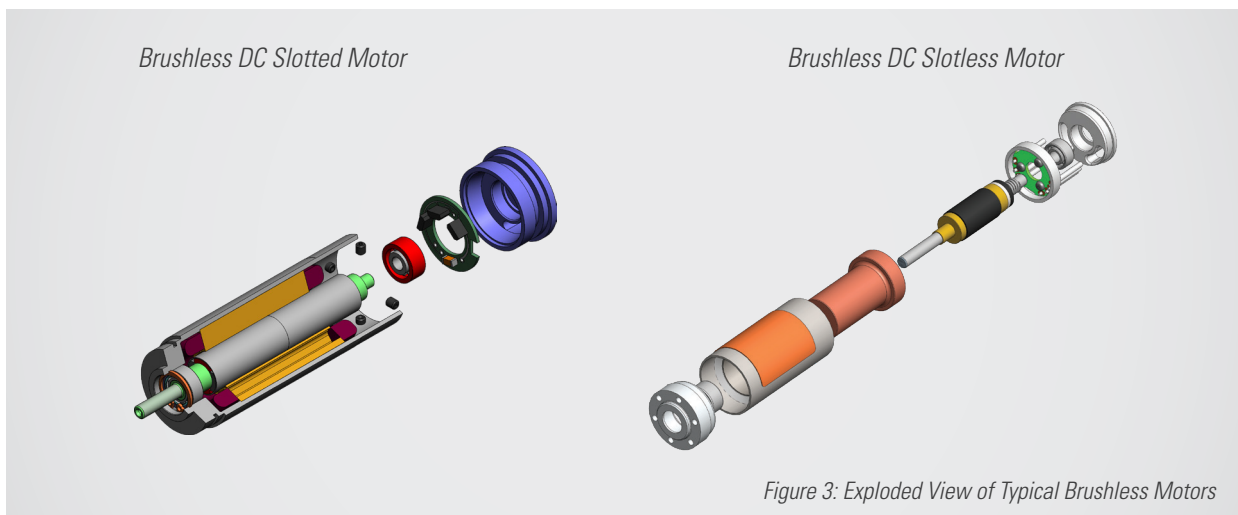


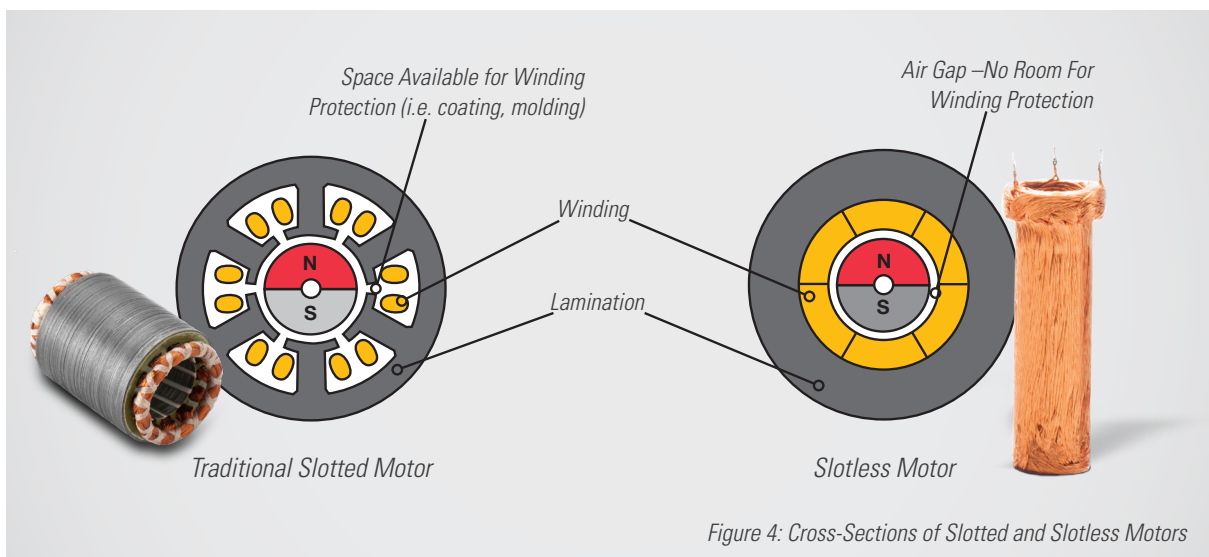
Figure 3: Exploded View of Typical Brushless Motors

Slotted BLDC technology has been a proven solution in the surgical motor market for more than 30 years. In a slotted design the copper coils are wound within the slots (Figure 4). The coil is inherently protected when inserted into the slots of the lamination stack. Additional insulation layers and molding material can easily be added without impacting motor performance. This physical configuration makes slotted BLDC the ideal technology for motors requiring extreme resistance to harsh environmental conditions, such as those seen in autoclave or during surgeries which expose the motor to saline and other contaminants. In addition, the slotted design provides:

- Easy customization to electromagnetics (windings, lamination stack length, etc.)
- Can reach very high dielectric resistance (1,600 VAC hi-pot or higher)
- Improved heat dissipation and thus higher continuous torque
- Small magnetic air gap, enabling the use of thinner magnets and providing higher permanence coefficient (which allows torque stability over large temperature range)
- Lower rotor inertia

Slotless BLDC, the other BLDC technology, is also very capable and may be well suited to the application. In a slotless motor, the coil is wound in a separate external operation and is of the “self-sustaining” type (Figure 4). The self-sustaining coil is then inserted directly into the air gap during motor assembly. In this design, the magnetic induction in the coil is decreased since the air gap is large. Induction in such a motor is usually much smaller than in a slotted BLDC motor, so a larger, more powerful magnet is typically required to compensate for the loss of induction. While slotless motors can be designed to withstand steam sterilization through insulation and other protective coatings on the exposed electronic components, achieving long-lasting and dependable protection from harsh environmental conditions is inherently more challenging when compared to a slotted motor. If autoclavability or very high numbers of sterilization cycles are not required – there are aspects to a slotless design that may be an advantage for a given application:

- Zero detent torque (i.e., no cogging)
- Smooth operation at very high speeds
- Increased motor inertia
- High peak torque capability



Precise Motion Control

For some surgical procedures or device design approaches, very high precision control of the motor may be required. This is often true for robotically assisted surgical devices which utilize sophisticated sensors, vision systems, haptic feedback or 3-D mappings to target material manipulation at the sub millimeter level. Successful execution of the surgery may require extremely high precision control of the motor output. The precision requirements may go beyond that which is delivered by traditional Hall sensors, which can detect rotor position in 60-degree increments. Utilizing an encoder can provide feedback for control of speed and positioning of the rotor at \ll 1-degree increments.

Encoders provide angular position measurements of the rotor shaft at a much higher precision than three Hall sensors can provide. Such feedback can be useful for position control or increased accuracy in the control of a BLDC motor. From the position measurements provided speed, acceleration, and direction can all be inferred. When looking for an encoder, one of the first steps is to determine the needed accuracy and resolution. The technology type must also be chosen; optical and magnetic are the most common technologies used for rotary encoders. Typically, in autoclavable applications such as surgical tools we find that magnetic encoders provide a robust and reliable option. Incremental or absolute feedback are two common options for communicating the angle value. If using incremental signals an index pulse, once per revolution, and a counter is needed to calculate the absolute angular position, otherwise the feedback is relative. Absolute feedback typically employs a serial communication line such as SSI, SPI, or BiSS in order to provide an encoded angle value between 0 and 360 degrees.

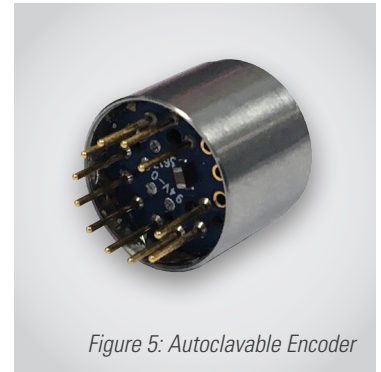


Figure 5: Autoclavable Encoder

Options include:

- Sterilizable option – designed and tested to 2,000+ autoclave cycles
- Hall sensor signals for 6-Step commutation (U, V, W)
- 10-Bit incremental encoder (A, B, Z)
- 11-Bit resolution absolute angle encoder
- Absolute position output via SPI
- Differential output for noisy environments
- Off-axis mounting allowing for cannulation

Conclusion

Modern surgical devices – both traditional hand tools and robotically assisted devices – have extremely demanding and exact motion requirements. Those requirements can be met by working with a motor supplier that has the necessary breadth of technology and vast experience with both traditional surgical hand tools and robotically assisted surgical devices.

About Portescap

Portescap is a manufacturer of miniature Brushless DC (both slotted and slotless), Brush DC, Stepper, and linear actuator motors, as well as related components such as gearheads, encoders, and controllers. Portescap is a leading supplier of sterilizable motors for powered surgical hand tools and robotically assisted surgical devices. Sterilizable slotted BLDC motors by Portescap have been used in tens of millions of surgeries worldwide, in every conceivable surgical application. Our engineering team has spent over 30 years continuously improving our sterilizable motor designs, which have been shown to survive in excess of 3,000+ autoclave cycles, far exceeding the useful life of a surgical

device. Portescap offers complete motor customizations tailored around surgical device needs: shaft cannulation, ground-up electromagnetic design, mounting features, custom gear ratios, pin connections vs flying leads, and more. Portescap's industry expert design engineers will collaborate with your team to customize any and all features for your unique surgical hand tool or surgical robotic application. **P**

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Typical Portescap Motor Applications for Surgical Robotics

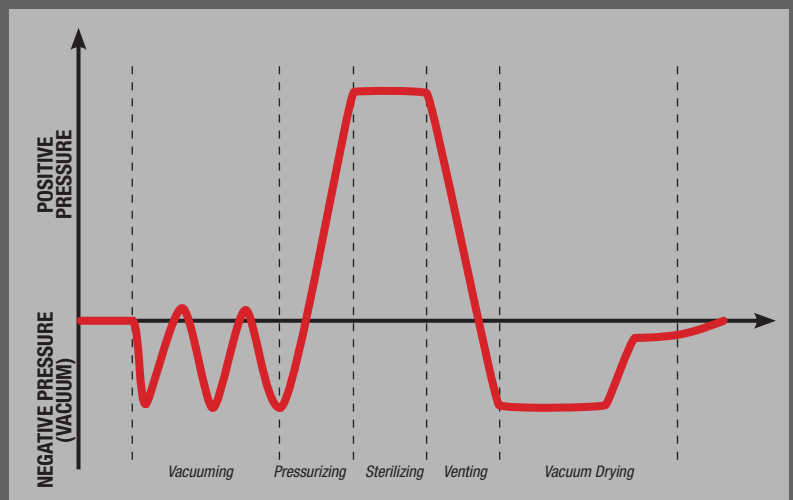
- Arthroscopic shavers
- Sagittal saws
- Oscillating saws
- Orthopedic drills, medium & high speed drills
- Wire drivers
- Surgical staplers



TECH TALK

WHAT IS AN AUTOCLAVE CYCLE?

The most common sterilization method used in hospitals is autoclaving, also called steam sterilization. During autoclaving, surgical hand tools are exposed to 100% humidity, 135°C (275°F) and pressure variations for up to 18 minutes. Most autoclaves also have additional vacuum cycles to facilitate steam penetration and kill bacteria, viruses, fungi, and spores that can hide inside microscopic cavities in the device. Repeated exposure to this environment is what typically causes significant electrical and corrosion problems for motors and devices that have not been sufficiently well-designed to withstand these conditions.



Pre & Post Vacuum Class B Autoclave Cycle