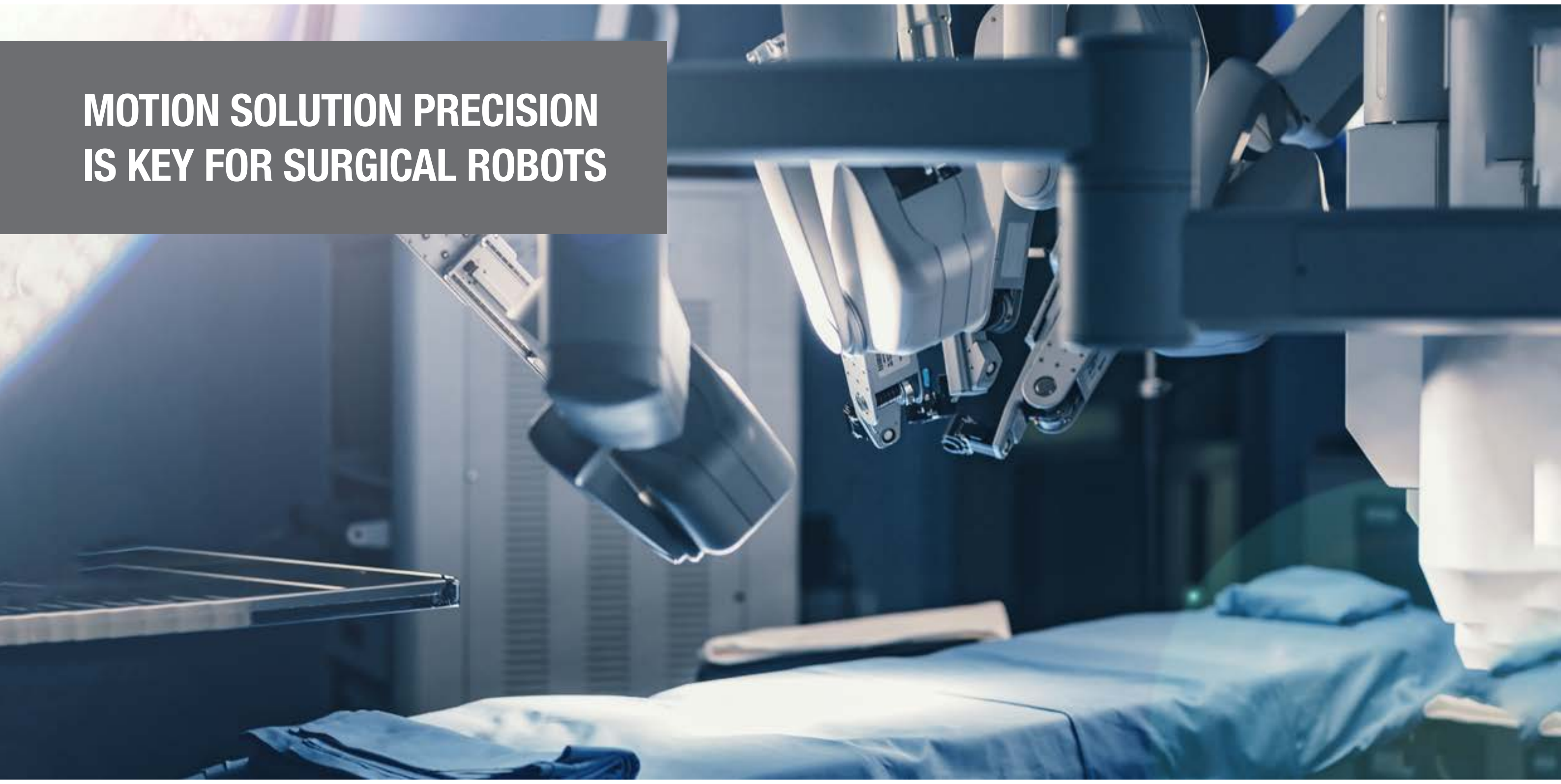
Portescap

A REGAL REXNORD BRAND

WHITE PAPER



MOTION SOLUTION PRECISION IS KEY FOR SURGICAL ROBOTS

The patient outcome of surgery performed by a robot is contingent on the control precision of its end effectors. Central to this delivery is the motion performance achieved by the robot's miniature motor system. Innovation in motion control precision has the potential to expand the array of surgical procedures that can be performed by robots. Meanwhile, for current robotic surgical applications, enhancing control precision means improved patient recovery. What steps should surgical robot designers take when specifying a motion system?

Enhancing precision in surgical procedures not only amplifies surgical efficacy but unlocks new potential for procedures previously deemed high-risk, greatly reducing damage to vital organs and nearby tissues. This paradigm shift in precision, driven by motion systems employed in surgical robots, promises minimally invasive techniques and quicker recovery times for patients.

Central to this evolution is the motion system's core component: the electric motor. Its zero-cogging feature, achieved through a brushless DC design and slotless structure, sets the stage for unparalleled control and responsiveness critical in robotic surgery. When coupled with considerations of power density, encoder performance, autoclavable capabilities, and customization, the standards of precision and performance for robotic surgery are redefined.

PRECISION ENHANCES THE PATIENT OUTCOME

The breakthrough in surgical precision advances surgical outcomes for patients across all spectrums and not only has the potential to increase the effectiveness of surgery, but could also enable procedures that were previously considered too high risk. In the future, the improvement in tool control could minimize the prospect of damage to organs and arteries in close proximity to the location of surgery.

Similarly, a smaller incision also minimizes the area of damage to healthy tissue. Even for robotic surgical procedures that are already considered ‘standard’, enhancing precision means improved patient recovery. The less invasive the surgery, the less time it can take to heal, and reduced scarring from a smaller incision can also minimize the potential for any future complications for the patient.

The central role of the motion system

The ongoing search for greater precision is the trend across all types of surgical robot development. This means that exacting control of the robot’s end effectors, holding and operating tools such as blades or grinders, is critical. Central to this capability is the motion system that drives and controls the end effectors.

Figure 1: Close up of a surgical robot end effector

The motion system’s key component is the electric motor, with its rotation controlling the position and speed of movement of the end effector. Smooth torque delivery is essential to ensure precision. To achieve this, the motor must overcome a phenomenon known as cogging, the periodic variation in torque that results in ripples during rotation.

While cogging can introduce relatively jerky motion, it can also reduce the responsiveness of the motor to control commands. Delays in achieving the desired position or trajectory of the end effector will inhibit haptic feedback and decrease surgical control where real-time responsiveness is essential. As a result, a motor that can deliver as close to zero cogging as possible is vital to optimise precision in robotic surgery.

Zero cogging

To achieve the smooth torque delivery, a brushless DC (BLDC) motor design is preferred. A BLDC motor uses electronics to achieve commutation, the process of switching the direction of current flow in the motor's coils to maintain continuous rotation of the rotor. Electronic commutation can also include integrated Hall sensors to optimize feedback and control of the electromagnetic circuit. This design is typically smoother than the mechanical method used by a brushed DC motor, where brushes make physical contact with a rotating commutator.

Figure 2: Portescap 35ECS80 Ultra EC™ brushless slotless motor

In combination, a slotless design minimizes the cogging effect. Traditionally, the stator, responsible for generating the motor’s electromagnetic field, is designed with slots that accommodate the copper windings and provide a path for the magnetic flux. Alternatively, in a slotless BLDC design, the windings are distributed evenly, allowing for a more symmetrical and continuous structure. This enhances the uniformity of the magnetic force distribution and achieves smoother motor operation. By optimizing this design, virtual zero-cogging can be reached.

Power density

The compact space envelope of an end effector on a surgical robot means that a small motion system is essential, but it still has to deliver the required torque for the operation. Optimizing the torque-to-mass ratio also helps to ensure that the motor can provide sufficient rotational force to overcome the delaying effect caused by any residual cogging.

In combination, minimizing a motor's inertia, or its resistance to changes in motion, can also improve the speed of response. Optimizing a motor's dynamism contributes to improved precision, and also helps achieve real-time control. Design and materials that can reduce the mass of the rotor are important considerations. Meanwhile, effective motor cooling techniques can minimize heat-induced resistance that would otherwise lead to an increase in inertia.

Combined with a BLDC design, the performance of an encoder is crucial to optimize control over the motor's position and speed. The encoder provides feedback to the controller on the motor's actual rotation characteristics to ensure precise control. This performance can be enhanced with a high-resolution capability.

The preferred feedback design for surgical robot applications is a magnetic encoder. Relying on sensing the motor's magnetic fields to identify position and speed, a magnetic encoder gives greater operational reliability in a surgical theatre compared to an optical design, where splashes and ingress of debris can obscure the sensor.

Figure 3: Portescap's M-Sense12A autoclavable magnetic encoder

Autoclave

A surgical robot's end effector may operate either inside of, or in extremely close proximity to, an incision during surgical procedures; because of this, both the end effector and the motion system driving it must be sterile to ensure patient safety and well-being. This sterilization is accomplished through an autoclave, which eliminates bacteria and microorganisms via high-pressure saturated steam.

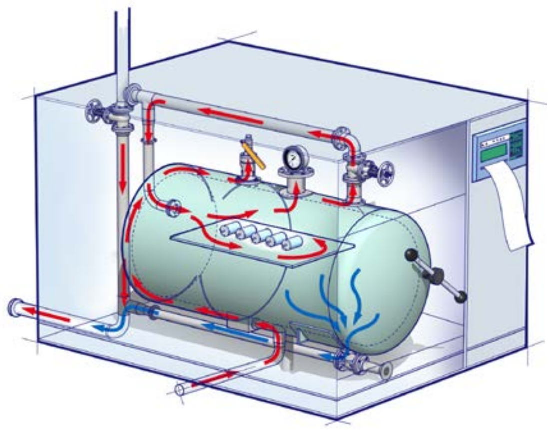


Figure 4: Rendering of an autoclave

It's critical that the micro-motion system be able to fully withstand the sterilization process. Enter Portescap, which has been at the forefront of innovating autoclavable motion solutions, with its brushless DC slotted motors and controllers guaranteed for a minimum of 1,000 autoclave procedures. Autoclavable encoders from Portescap are designed to withstand at least 2,000 autoclave cycles, while gearheads are rigorously tested to endure 3,000 cycles or more. The method of design and sealing with a high IP rating, along with continuous innovation in materials development, ensures the durability of these components.

Customization

Although the need for control precision and durability for sterilization is common across motion systems specified for surgical robots, each OEM usually has specific design requirements. This often involves specific torque and speed profiles, as well as control characteristics. The form of the host robot may also need specific mechanical integration, which could include a customized footprint or even a frameless motor design. As a result of these specific needs, around 80% of Portescap's motion system development is for custom applications.

To maximize the benefits of the customization approach, it's advantageous to involve the motion team early in robot design. Sharing full visibility of the requirements from the outset can speed up development and minimize the need for rework or adaptions at a later project phase. This also challenges the perception that an off-the-shelf motor design can reduce time to market. Although a catalog-selected motor can save time initially, the design adaptions required can extend the project length beyond that of the custom approach.

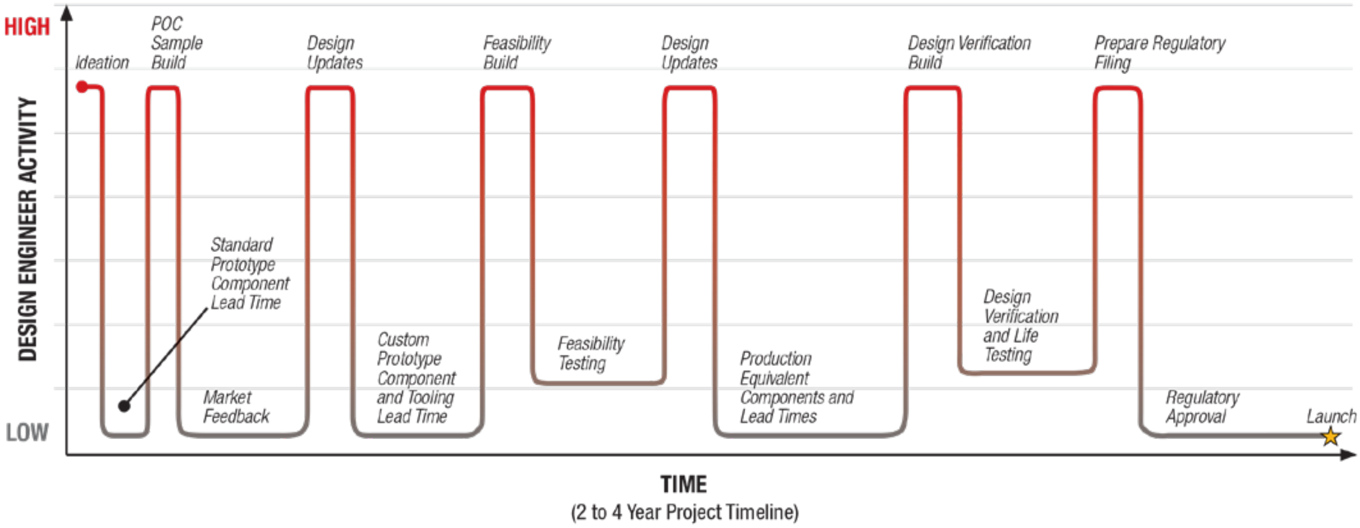


Figure 5: Ideal project design timeline

Instead, a motion system tailored to the surgical robot's specific operational parameters removes the need to compromise. A custom approach will achieve the optimum balance of motion performance, combined with ease and speed of design integration. **P**

FOR MORE INFORMATION:

110 Westtown Road
West Chester, PA 19382
T: +1 610 235 5499
F: +1 610 696 4598
portescap.sales.america@regalrexnord.com
www.portescap.com

CONTACT AN ENGINEER:
www.portescap.com/en/contact-portescap

Paul Schonhoff
Business Development Manager
Portescap
A REGAL REXNORD BRAND