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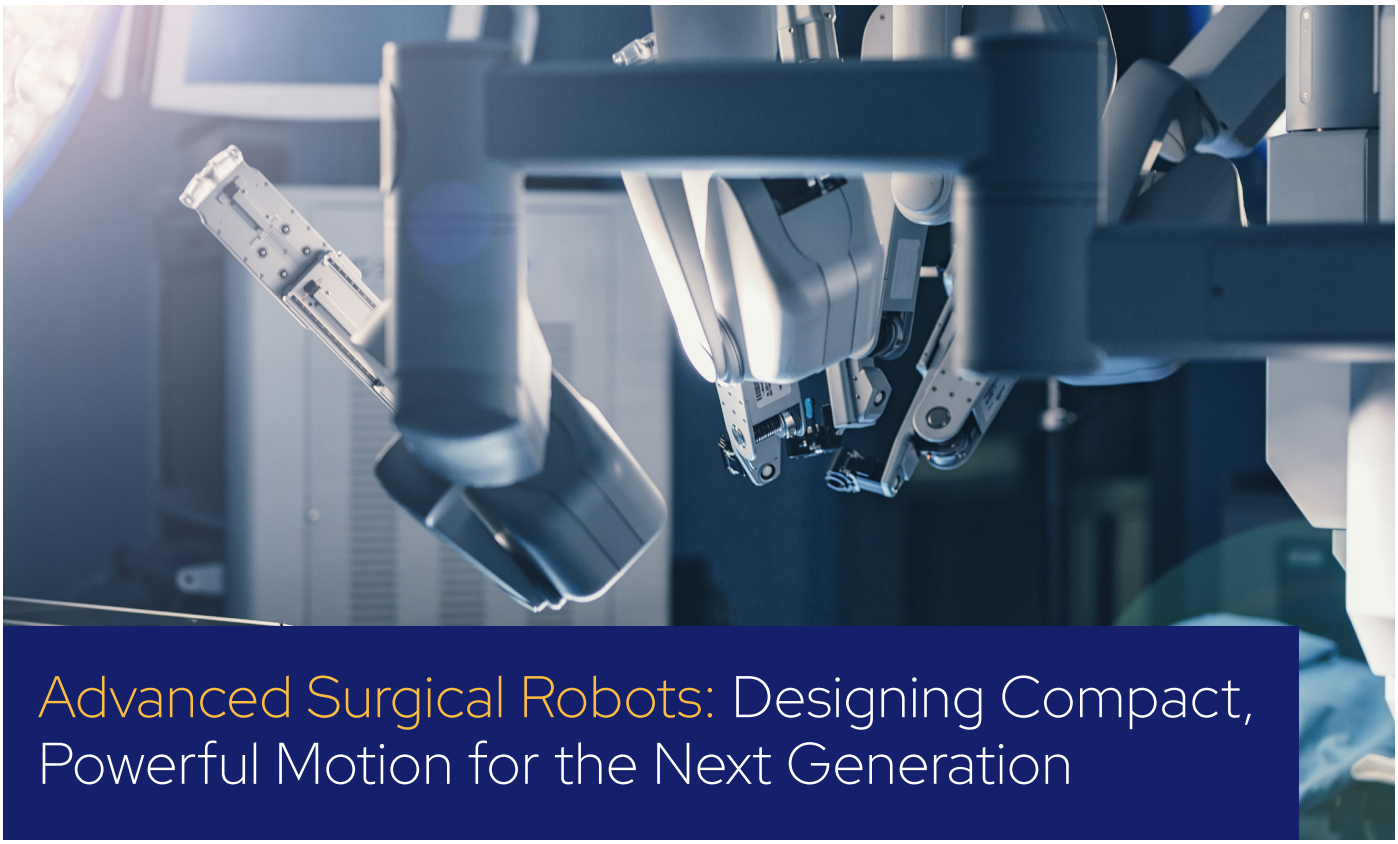


Advanced Surgical Robots: Designing Compact, Powerful Motion for the Next Generation

Conventional surgical robots include large columns with multiple arms holding tiny cameras and various instruments such as scissors, graspers, needle holders, clip applicators and more. For the greatest flexibility in performing procedures, surgeons want the freedom to manipulate these instruments at their chosen angle, without constraint.

Often, surgeons prefer to make incisions that are as small and as few as practical to minimize patient discomfort and improve outcomes. For many cases, the ideal procedure would be performed through a single, small incision that can simultaneously accommodate visualization cameras and all needed instruments.

This ideal can be difficult or impossible to achieve, as the conventional robot design doesn't allow for instruments to approach the site at an acute enough angle.

The challenge for surgical robot designers, then, is to enable the arms to operate as closely together as possible, so that instruments and cameras can enter the incision nearly in parallel. This freedom of motion can help to minimize the invasiveness of the procedure, improve the surgeon's angle of view, and allow for unconstrained dexterity when manipulating multiple instruments.

Part of the solution to this challenge is placing the articulated arms on smaller columns in a multiple-column design, so they can be positioned independently and closer together. However, even in this design, the limiting factor is the width of the arms themselves as constrained by the effective width of the arm joints.

How can engineers design arm joints that are axially more compact without compromising the precision and performance required for delicate, life-changing or even life-saving surgeries?

Design considerations for axially compact arm joints

To achieve next-generation capabilities, surgical robot designers must solve several challenges. Chief among them is delivering all the torque, speed and precision required for the application while minimizing the effective width of robotic arm joints.

Precision is of paramount importance. For all robotic joints, motor and gear sets must deliver smooth, precise acceleration/deceleration and rock-steady holding capabilities. Specific torque and speed requirements may vary, however, depending on the function of each joint.

Motor torque is especially important for joints farther from the operating site that must support the cumulative weight of arms, joints and instruments at the end of the arm. Motor speed is less important for controlling instruments at the end of the arm, where surgeons value precise, small-scale motion over speed. However, motor speed does matter for the efficiency of joints that perform larger positioning motions.

Thermal rise can also be an important consideration. It's essential to avoid excessive temperatures within the small confines of robotic joints, which could otherwise degrade lubrication in the bearings and gearbox next to the motor or hinder the function of thermally limited electronic feedback devices.

SOLVING THE SIZE CHALLENGE

All of these challenges are compounded by the overriding challenge of designing the joint to be as axially compact as possible to give the surgeon greater freedom in the placement and manipulation of instruments. **How can you solve for small?**

BEGIN WITH GEARBOX SELECTION

Based on the required dynamics of each joint, select strain wave gearing that will deliver the required average and maximum torque, provide sufficient stiffness, ensure long service life, and meet your other design requirements.

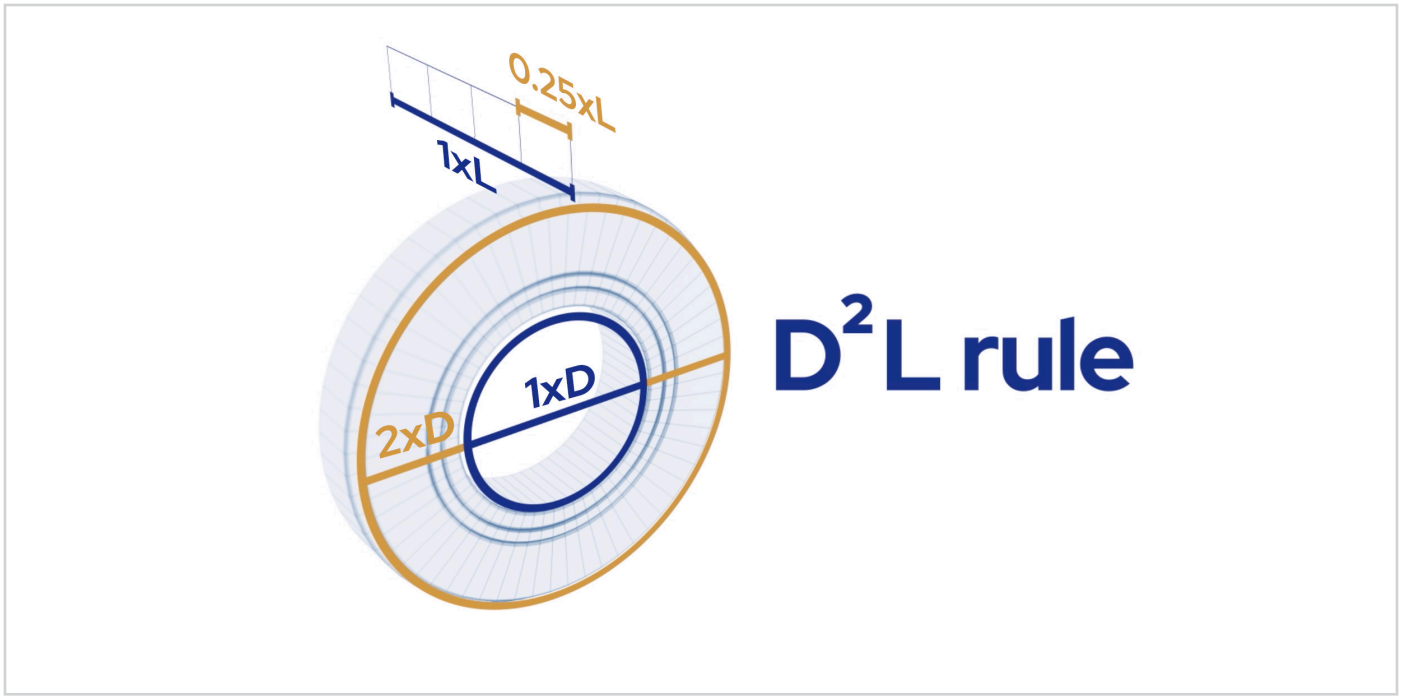
Strain wave gearing (also called harmonic gearing) is by far the preferred choice for this type of application. It exhibits zero backlash for the most accurate positioning and reliable holding. It delivers high reduction ratios in a single stage for high power density and smooth acceleration/deceleration. And crucially for solving the size challenge, strain wave gearing can be extremely compact axially.

In your selection process, consider whether a relatively larger outer-diameter gear set could meet your design requirements, enabling you to take advantage of the D^2L rule by using a larger-diameter motor.

In surgical robot design, you're likely to be far less concerned about joint diameter than axial dimension, since the goal is to allow the multiple arms to work as closely together as possible. The D^2L rule states that torque increases in direct proportion to an increase in motor lamination stack length. Or, it increases as the square of an increase in moment arm diameter.

In other words, doubling the diameter of the moment arm produces a fourfold increase in torque—or, alternatively, allows the stack length to be reduced by three-fourths with no loss of torque. A larger-diameter gearset, accommodating a larger-diameter yet much shorter motor, can make a big difference in your effort to minimize effective joint width.

One final consideration: Can you meet your design requirements—including your preference for a larger diameter motor—in a commercial off-the-shelf gear set? If so, you can avoid the time, risk and expense of a custom gearing design, bringing your robot to market faster at a lower cost.



NEXT, SELECT THE OPTIMUM SERVO MOTOR

Your choice of servo motor must fit with your choice of gearing, which is why it comes second in the selection process. Beyond basic fit, however, there are several selection criteria that can help you achieve the most successful design.

The motor is the principal factor determining how compact the design of a robotic joint can be. Given equivalent performance characteristics, a motor with a shorter stack length will allow for an axially narrower joint, which is the goal. Even a few millimeters saved can make a big difference in the surgeon's experience and control.

Joint diameter is less of a consideration than stack length, since diameter doesn't affect the relative positioning of adjacent arms. As we have seen, the D^2L rule means that any increase in moment arm diameter can allow for a much greater decrease in stack length with no loss of torque. That's a huge opportunity to save space where it counts the most.

In addition to overall motor sizing, consider whether a large thru-bore is needed to accommodate wiring, optical fiber, fluid tubing or other components. With the multiple axes needed for fine-tuned positioning of instruments, considerable space is required to run the power and communications cables needed to control each axis, and you don't want these cables to consume space beyond what's required for the motors themselves.

Also consider compatibility between the motor and your choice of feedback devices. Typically, dual feedback is required for this type of application, including a high-speed input shaft feedback sensor and an absolute output shaft feedback sensor. High resolution is a must. Both sensors can add to the width of the joint. Focus on how well these devices integrate with your possible motor selections.

Take into account the motor's thermal rating and whether it will be compatible with temperature-sensitive components within the restricted confines of the joint. Will the motor require operation at less than its rated maximum winding temperature to avoid the potential for damage or premature failure of system lubrication, thermally sensitive feedback devices, or other components? If so, will a motor operating below its temperature rating still deliver the torque and speed required for the specified load? These considerations are particularly important for joints closer to the column, which must support the load of joints further out on the arm.

As with gearing, if an off-the-shelf motor can meet all these needs, you can save development time and expense compared to specifying a fully custom motor. With any choice of motor—standard or custom—make sure the supplier has a sterling reputation for motor quality, availability and support.

Nothing can derail your project like a motor you can't count on to fit and perform with absolute consistency in the operating room, delivered with the quality you need in the quantities you need now and throughout the lifecycle of your surgical robot.

COMPACT AND POWERFUL, TBM2G MOTORS ARE ROBOT-READY

At Kollmorgen, we believe the motor should be designed to fit the application, not the other way around. Our TBM2G series of frameless servo motors is designed specifically to fit the dimensional, torque and speed requirements of standard strain wave gearing for compact surgical robotic joints.

TBM2G motors take advantage of the D^2L rule to deliver full performance in the most lightweight, axially compact joints. They also feature a large thru-bore to accommodate wiring and other components that pass through the joints of a complex surgical robot arm.

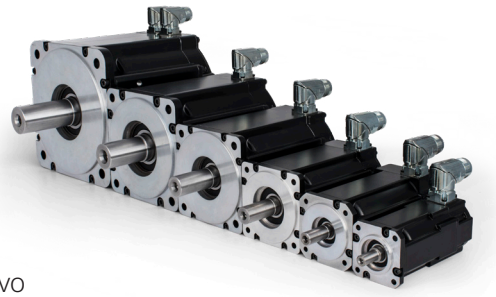
TBM2G motors work with a wide range of encoders and can even be supplied with integrated Hall sensors that don't increase motor length. With an exceptionally low thermal rise, these motors can operate in close proximity to temperature-sensitive components with no performance compromise.

Kollmorgen offers these motors in a wide range of sizes and standard options, allowing you to achieve an ideal fit. A choice of winding variations optimizes motor performance at various bus voltages, including windings that are ideal for battery-operated and mobile robots.

The TBM2G series is built to the highest standards of quality, with the manufacturability, delivery and support you need to take your robot from prototype to full-scale production at any volume, anywhere in the world.

Design considerations for smaller, lighter robot columns and patient tables

Surgical robots are amazing machines, but can be large. Minimizing space requirements can make for a more marketable robot that saves space in the operating room, can be used in smaller rooms, or can even be mobile.



The columns that support and elevate robot arms and the axes that control the orientation of the patient table can all be made smaller and lighter without compromising system design or performance. The key is to use servo motors that offer the highest torque density in the most compact package.

AKM2G MOTORS DELIVER HIGHER PERFORMANCE IN A SMALLER FOOTPRINT

Kollmorgen's AKM2G housed servo motors provide substantially greater torque density in a smaller package compared to other servo motors in their class. Integrated into existing systems, they can substantially improve performance with no change to motor mountings or footprint. In new systems, they deliver all the required torque and power in the smallest practical space.

AKM2G servo motors are available in a wide range of sizes and windings, and they can easily be configured to suit specific application requirements. Standard modifications include stack lengths, encoder options, thermal sensors, special windings and gauges, mounting dimensions, dual/single/hybrid cables and connectors, environmental sealing and more.

Like all Kollmorgen motors, AKM2G servo motors are built to the highest standards of quality, reliability and global availability.

Design with a motion expert

Whether you're an established robotics company or a start-up, motion is critical to the performance and footprint of your robot platform. Choose a partner who:

- Solves motion problems and helps meet the standards that matter to you, with the ability to configure products to fit your unique design requirements.
- Delivers the products and expertise you need to help reduce design time and increase speed to market.
- Provides collaborative engineering support from concept through production.
- Does not constrain your choices of feedback devices, brakes or other components.
- Offers reliable delivery and support for your surgical robot throughout its lifecycle—from rapid prototyping through all rates of production to long-term sustaining engineering—anywhere in the world.

KOLLMORGEN IS WITH YOU ALL THE WAY, WITH PROVEN PROCESSES AND RELIABLE DELIVERY

We'll work with you in the initial design phase to understand your exact requirements, then provide the engineering support you need to simplify motion system selection, sizing, configuration and programming. With our extensive configuration capabilities, we'll rapidly prototype, deliver and iterate your solution as needed to potentially save months in your development process.

When the final design is ready, we'll fully document it and help usher it through any required certifications, in any region. With our lean manufacturing, repeatable processes and quality controls, we'll quickly transition from prototype to full-rate production, delivering your motion systems on time, every time. And we'll provide long term support, in-region/for-region, to sustain product delivery throughout the lifecycle of your robot, managing costs while scaling production as needed.

READY TO MOVE FORWARD?

Contact Kollmorgen at www.kollmorgen.com/en-us/service-and-support/contact-us to discuss your needs and goals with a Kollmorgen expert for healthcare applications.

About Kollmorgen

Kollmorgen has more than 100 years of motion experience, proven in the industry's highest-performing, most reliable motors, drives, linear actuators, AGV control solutions and automation platforms. We deliver breakthrough solutions that are unmatched in performance, reliability and ease of use, giving machine builders an irrefutable marketplace advantage.

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