Portescap

WHITE PAPER

TRENDS IN ROBOTICS ARE EXPANDING THE NEED FOR MINIATURE MOTORS

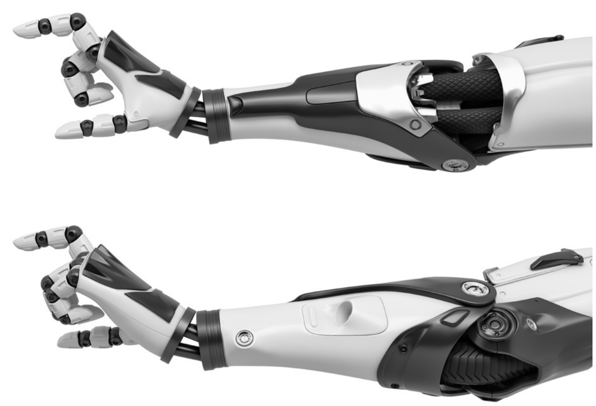
Background

Advancements in automation and artificial intelligence are driving innovation in robotics - expanding into new industries with the emergence of smaller and smarter robotic designs. New developments in vision systems and sensor technologies require inventive applications for robots in the medical, warehousing, security, and process automation fields. Disruptive technologies create new opportunities for miniature motors to solve the unique challenges of the robotics market; including, the predictable control of surgical tools, the safe and efficient navigation through warehouses, or the necessary endurance to complete lengthy security missions.

Emerging Trends in Robotics

Trend 1: Mobility and Footprint

Transition to collaborative robotic applications requires systems to be mobile, dexterous, and compact. Tasks typically handled by human hands drive the need for miniaturized motor solutions that can both mimic the size and capabilities of the hands used to do work. What does this mean for motion control products?



Robotic actuators require small power-dense motors to reduce the overall size and weight, especially in multiple jointed solutions (wrist, arm, elbow, torso). Compact solutions improve usability, autonomy, and safety (faster reaction time due to lower inertia). Humanoid robots, prosthetic arms, exoskeleton, and robotic grippers typically have requirements for a small, high power density unit. Power density is the amount of power (time rate of energy transfer) generated per unit volume of the motor. A motor generating more power in a smaller package increases power density, which is important where space is constrained or where maximum output is needed in a fixed space. High power density allows the miniaturization of mechanisms or an increased capability in current designs, which is critical to reduce the space consumed by the motion elements. Efficiency is key in getting the most power possible out of a given design with Brushless DC motors playing an important role in size reduction over conventional DC motors. Slotless motor designs, combined with efficient planetary gearboxes, offer a very powerful unit in a small package. Whether the need is for a short, flat, low-profile configuration, or a long and skinny design, brushless solutions can be engineered to meet specific customer requirements.

Dexterity and agility require a dynamic response and smooth operation. Slotless BLDC motors eliminate detent torque and provide precise dynamic motion with lower inertia motors. In high dynamic applications requiring constant acceleration/deceleration (such as delta robots and pick and place systems), high acceleration characteristics are critical. Coreless DC motors and Disc Magnet stepper motors, having very low inertia, making them the right solution for such applications.

High efficiency, ironless brush DC motors are the best choice for mobile, battery-powered applications to extend operational life between charges. Many robotic applications run on battery power, so require very efficient motors (up to 90%) to provide longer running time. Certain applications require high torque at lower speeds, achievable by matching the motor with a highly efficient gearbox (up to 90%). Inefficient gearbox designs negatively affect overall system efficiencies, decreasing battery operating time, while increasing costs.

Trend 2: Robustness and Extended Life

Robot systems used in applications inhospitable to humans may need to endure difficult environmental conditions, including tremendous shock and vibrations. Motor construction plays an important role in reliability and durability. Motors with metal housings and flanges are well suited for harsh environment applications, including surveillance, inspection of industrial pipelines and sewers, power grid patrol, and autonomous guided vehicles in warehousing. When under these temperature / pressure extremes and other hazardous conditions, a well-designed motor will provide additional life over standard motors. Robots in surgical applications are required to endure repeated high temperature and pressure cycles during the sterilization process. To match these demands, the motor design includes encapsulation of electromechanical and electronic components. The design upgrades may extend the life of the motor multiple times, allowing the surgical robot to complete many more surgeries before maintenance on the motion control is necessary.

Trend 3: Safety and Analytics

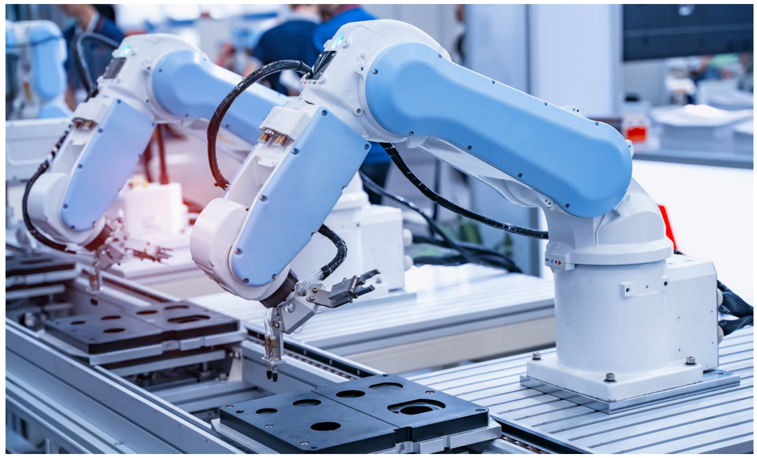
Collaborative robots, working side by side with humans, must operate safely and predictably when faced with an obstacle. Feedback devices, such as encoders, thermistors, and current sensors, have a role in protecting the operator, the patient, and the robot. High-resolution encoders provide the precision required to achieve critical positions repeatably, improving yield over the course of a work shift.. Thermistors and other temperature devices alert operators when temperature limits are about to be exceeded, enabling operations to be ceased temporarily to determine the source of the issue and corrections completed. On the production line, a robot failure can mean lost productivity so the analysis provided will save time and money. Precision current sensors can detect inadvertent interactions with personnel, stopping the robot quickly before any damage or harm occurs.

Many robotic systems also collect various data related to work completed as well as self-diagnosis to facilitate predictive maintenance. Thermal or force sensors integrated into motors provide real-time data to improve productivity by quickly identifying deviations in expected force levels. A higher than expected force required to complete the installation of a screw can alert the system to a pending issue, allowing a rapid update to the system to continue production. Increased current consumption over time can institute predictive preventative maintenance cycles. A surgical robot would provide the details for a motor replacement to prevent unexpected stoppage during an operation.

Trend 4: Autonomy and Multi-axis Control

The future of robotics is to continue incorporating autonomy and machine learning. Warehousing applications rely on faster order to ship times with autonomous vehicles relying on self-navigation and accurate information to operate safely. LiDAR (light imaging, detection, and ranging) is used to capture 3D imagery of the environment while scanning at very high refresh rates and relying on high-resolution feedback with minimal latency. Fine pitch optical sensing systems, together with high capability interpolation processors, provide incremental position information (16 to 20 Bits) in near real-time with a mechanical error in the range of 0.25 mechanical degrees. Using new sensor technologies, in conjunction with the latest optimized motor designs, enables innovations as to where and how autonomous vehicles can operate.

When tasks that traditionally required human intervention are replaced by automation, the robotic solution requires coordination of numerous axes of motion and in some cases to be guided by a vision system. Multi-axis applications, such as surgical robots, are taking advantage of serial interface communication protocols (like BiSS or SSI) that allow daisy chain connections of encoders to minimize wiring complexity. Bulky mechanisms are streamlined by incorporating miniature motor technology coupled with advances in sensor technology containing serial interface capabilities. Encoders with serial interface communication provide absolute position information based on magnetic sensing technology, with a typical resolution of 14 bits and accuracy in the range of 1 mechanical degree.



Miniature Motor Types

The robotics market is a big consumer of electric actuators to execute motion. Different types of motors, gearboxes, and encoders are used and selected according to the application requirements, including Ironless Brush DC (direct current), Slotted and Slotless Brushless DC, and Stepper motors, which include Can Stack, Hybrid and Disc Magnet motors. Each motor technology has benefits uniquely suited for its respective robotics applications.

Criteria	Slotted BLDC	Slotless BLDC	Brush DC Coreless	Stepper Hybrid	Stepper Disc Magnet	Brush DC Iron Core
Typical Applications	Surgical Robotics, Exoskeletons	Lidar, Gripper	Service: Bionics, Humanoids, Inspection	Robot Joints, Actuators	Gripper	Consumer Products (e.g. Vacuum Robots)
Long life	+++	+++	++	+++	+++	+
Efficiency	++	++	+++	+	+	+
Torque density at low speed	+++	++	+++	+++	+	++
Torque density at high speed	++	+++	++	+	++	+
Power density / Size	+++	+++	+++	++	+	+
Acceleration / Dynamic	++	++	+++	+	+++	+
Robustness	+++	++	++	+++	++	+
Cost	+	+	++	+++	+	+++

Robotics Applications Suited for Miniature Motors

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.

Service Robots

Robotic applications are taking on new roles in unmanned inspection, security, and patrolling in operating environments that are not safe for humans or are highly repetitive. These systems go well beyond just providing the stationary cameras and alarm systems of the past. Typical uses include surveillance and inspection of industrial pipelines and sewers, power grid patrol, and autonomous guided vehicles in warehousing.

Coreless Brush DC and brushless DC motors, along with their complementary gearboxes and encoders, are the ideal motion solution to provide high torque and extended battery operating time in a lightweight package

LiDAR

LiDAR technology enables machines to access the current environmental conditions in 3D, develop a response, and then navigate the situation. Machines using LiDAR range from small service robots to large autonomous vehicles with the ideal LiDAR system being compact, lightweight, precise, and cost-effective. Customers prefer flat motor configurations for compactness and minimum weight and medium to high-resolution encoders for precision feedback.

Electric Grippers

During the last decade, the conversion from pneumatic to electric technology in industrial gripping has gained popularity since electric grippers allow better control of the gripper finger position, grip detection, and control of the grip force and speed.

Slotless Brushless DC motors, along with their complementary gearboxes and encoders, offer the high-power density, low inertia, high precision, and low weight needed to meet application requirements.

Surgical Robotics

Surgical robot applications have unique requirements regarding compact size, low weight, high power density, and sterilization. While not all motors within a surgical robotic system require a sterilizable solution, other requirements may focus on the robustness and durability of the motor, such as in autoclave applications. In these applications, electronics (stator and commutation electronics) are fully encapsulated in a thermoset epoxy, ensuring that the high temperatures and pressures encountered in the steam autoclave environment do not adversely affect the electronics.

Within the growing field of surgical robots, a high degree of variability makes it infeasible to create a single solution for all customer applications. Even within the customer's system, there may be distinct differences in the types of motors that are articulating the various axes or driving end effectors. These unique specifications require highly customizable solutions (both electrically and mechanically) to meet the needs of the customer's robotic system. Customizing the design for a customer application ensures that the performance goals are met within a defined package size. By understanding the constraining load points, a solution can be developed that meets the optimum torque and speed balance in the most compact and light-weight design possible.

Conclusion

Portescap is a unique company developing different motor, gearbox, and encoder technologies to deliver the best solution for customers with power requirements below a few hundred mechanical watts.

Portescap's multi-technology offerings and collaboration expertise are big advantages for customers - providing several technology choices for an application, each offering specific advantages in meeting critical requirements. Portescap specialists, with decades of experience in solving the most challenging motion applications, create uniquely tailored, cost-effective, robotic solutions not possible with a standard motor.

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.

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