Technology Handbook

Digital supplement to
MANUFACTURING AUTOMATION

MOTION CONTROL

A look into the products, technologies and solutions shaping the market

ADVANCED MOTION CONTROLS
...driving the world's best robots!

Motion control considerations for Robotics

by Karl Meier, Executive Team – ADVANCED Motion Controls

The rates at which physical robots are integrating into society today has increased so much that new categories are being created for their use and general purposes as well as dedicated designs versions compete for acceptability. The future of robots and robotics technologies is an economic area where it can be projected that new companies with new achievements will be some of the largest in the world in a short period of time. Intelligence is key to robots but what makes robots move so they can accomplish the activities they are designed to do is vital to their performance, and ultimately their existence. This brief article introduces the many aspects of motion control needing consideration when applying drive technology to robotic systems and platforms.

Any mechanical object that moves generally has a motor for operation. The electric motors incorporated into robotic designs are based on needed torque/force, speed and acceleration/deceleration parameters and are typically going to be either servos or steppers. In industrial robotics platforms, each motor selected will have a controlling drive that operates the motor to ensure required performance. By design and construction of each, servo systems are much more efficient than steppers and offer a much wider operating range. As servo drives are more widely used and accepted, the focus here will be on servo-based motion control.

Robots can have many different axes needing motion control and likely will include more than just main mobility of either propulsion or traction. For instance, there can be separate steering, arm extension/retraction, gripping, joint rotation, lifting, haptic feedback, etc. All of these functions usually incorporate a drive specifically tuned for that axis to provide the necessary controlled motion. The drives themselves receive commands from a supervisory controller that also maintains overall functionality of the entire system/platform. Motion control for the entire robotic system has traditionally been categorized into two areas: centralized or distributed.

A centralized control scheme requires the controller to continually calculate all torque/force, speed and position commands (called the control loops) for every axis, while simultaneously running complex programs that plan not only the motion profiles but also scan I/O or vision information to maintain complete robot operations. This can place a heavier burden on the processor(s) selected for use and may make the system unmanageable when increasing scalability.

In distributed control systems, motor control requirements are placed with the drives themselves and conducted over network communications where the controller merely monitors activities of the drives with limited computation needed. This allows the controller to operate more effectively and be more available for all other system functions. There are numerous networks to choose from as well as standardized function calls allowing motion control and system functionality to work very closely together. CANopen, EtherCAT, Modbus, Ethernet POWERLINK, PLCopen, etc. offer fully documented methods of getting up and running quickly and greatly reduce development time.

As robots need to manage on-board power as much as possible for continued operation, the choice for servo drives is wise as they are most efficient. This includes a power range from 10Watts to more than 50kW! However, and along with the servo motors, drives need to be 'sized' appropriately. Since the robot will have a pre-established voltage level available to the drives, sizing relates to being able to provide the minimum current required to allow the motor to maximize its abilities. As well, drives are offered in various platforms to include available back-plane mounted and PCB plug-in module versions, both with standard and extended environment capabilities. Custom designs are also available allowing robot OEMs to 'think outside of the box'. Custom engineered designs provide the prospect of achieving results not otherwise possible and often at costs less than that of off-the-shelf designs.

This information and insight has provided many industries with application excellence using servo driven robots and robotic platforms. For example: Material Handling's - Palletizers, Sorters, Automated Fork Lifts; Warehousing's - Storage & Retrieval Systems, Automated 'Pick & Present' Systems; Manufacturing's - Automated Guided Vehicles (AGV's), Transfer Lines, Assembly Cells; Medical's – Surgical, Scanning Systems; Homeland Security and Defense's: Unmanned Vehicle Systems (UVS's) for Air, Ground and Submersibles, Remote Control Detection; Service's – Telepresence, Inspection, Repair and Delivery.

Many more robots exist and many more are coming. Stay tuned to what the future holds…

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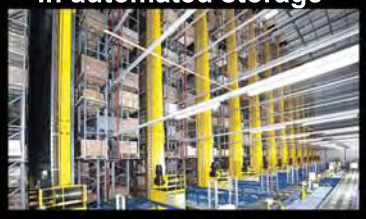

On the battlefield

In material handling

In extreme environments

In communities

In fabrication

***ADVANCED* Motion Controls®** servo drives are specified & installed anywhere from factories and production facilities to extreme environments; from under the surface to the vacuum of space; from start-ups to multi-national companies; from security firms to national defenses and law enforcement agencies around the world.

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In the operating room

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With telepresence

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On transfer lines

FESTO

A handling system in just 10 minutes

The right standard handling system including CAD model in just a few clicks - that's what Festo's Handling Guide Online can do for you. The individual steps, enquiry, design, offer, CAD design and order which previously took 10 to 15 days can now be done in just 10 minutes thanks to the configuration and ordering platform.

The Handling Guide Online is opening up new horizons. Sifting through catalogues, tedious supplier RFQs, ordering single components and complex individual constructions for handling tasks are thus a thing of the past forever. Thanks to the new software tool, design engineers gain time for planning and project engineering processes for their companies' core areas of technological expertise. A large part of the engineering work is eliminated and detailed product knowledge is no longer required. Intuitive software with structured data polling ensures reliable selection of the right components from Festo's modular handling system.

Three steps to the right handling system

Just three steps are all it takes to arrive at a fully configured handling system. During the first step, the engineer selects the desired type of handling system and enters the application data in the Handling Guide Online. The tool suggests appropriate handling systems. During the second step, the planner selects the most suitable handling system from these suggestions. The data sheet and the correctly configured CAD model are immediately made available for download in all common data formats for direct integration into the customer's own design engineering system.

During the third step, the engineer uses additional options to configure the selected system in accordance with his own requirements. With a single click the preferred handling system is transmitted to Festo and their handling experts will then contact you to discuss and confirm your request. Festo will deliver a ready-to-install system including all user documentation specifically for the machine or plant within an extremely short lead-time.

Individually developed

In addition to flexible standard products, Festo also develops handling systems based entirely on individual, industry-specific requirements, for example with freely definable axis geometries for shorter cycle times or for integration into machines with minimal space requirements. If the handling systems suggested by the Handling Guide Online should fail to meet the specified requirements despite the great variety of options, the design engineer can simply forward the entered application data to Festo's handling experts with a single click to obtain a personalized quotation.

Time-to-market reduced

As well as saving on design and ordering, the standardized handling systems also reduce the assembly and delivery times from a little under two months to just a few weeks. The parameterization and commissioning time is also significantly reduced. Machine and equipment manufacturers are thus able to reduce their time-to-market by up to 70% with regards to integrated handling systems.

Start your project now at
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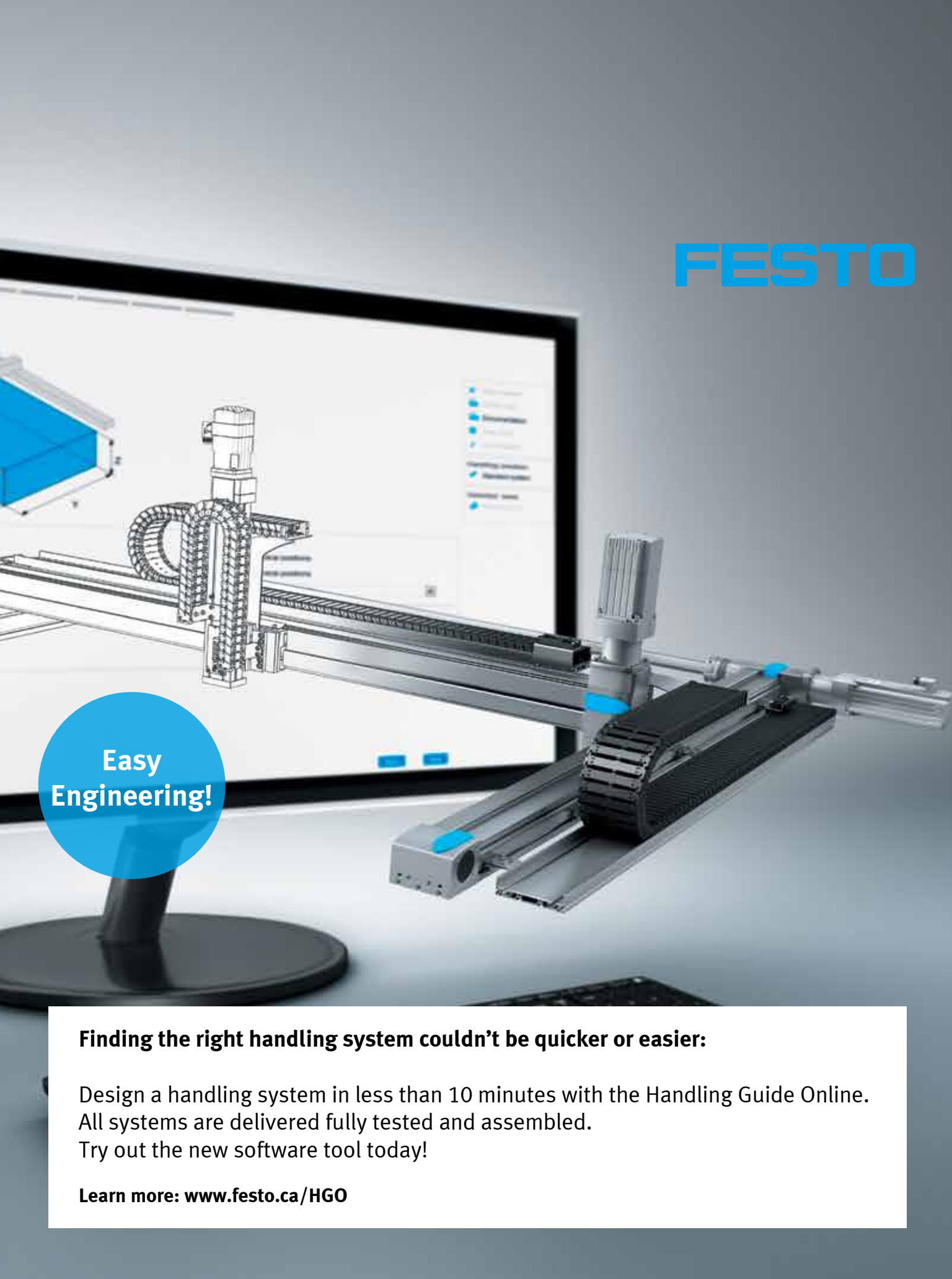

Finding the right handling system couldn't be quicker or easier:

Design a handling system in less than 10 minutes with the Handling Guide Online.
All systems are delivered fully tested and assembled.
Try out the new software tool today!

Learn more: www.festo.ca/HGO

Harmonic Planetary® Gears Offer Low Backlash for Life.

New models are being added to our planetary Quick Connect® gearhead line. Building a high precision actuator is easily achieved by coupling any servomotor to one of our precision Quick Connect® servo gearheads.

Planetary gears have simultaneous meshing between the sun gear, planet gears, and the internal ring gear. Harmonic Planetary® gears use a precision engineered elastic ring gear which compensates for interference between meshing parts. This proprietary Harmonic Planetary® gear design provides smooth and quiet motion and maintains ultra-low backlash for the life of the reducer.

Harmonic Planetary® Gears

- Ratios: 3:1 - 50:1
- Peak Torque: 3.9 N•m - 3940 N•m
- Sizes: 40mm - 230mm
- Output Configurations: Hollow Shaft, Flange, Keyed Shaft, Smooth Shaft

HPN Planetary gearheads are priced to deliver a great value. They feature a robust design utilizing helical gears for quiet performance and long life. These gearheads are available with short lead times and are designed to couple to any servo motor with our Quick Connect® coupling. HPN gearheads are suitable for use in a wide range of applications for precision motion control and positioning. HPN Harmonic Planetary® gears are available in 5 sizes: 11, 14, 20, 32, and 40, with reduction ratios ranging from 3:1 to 50:1. Plus, they are dimensionally compatible with popular gearhead models. This new value series of planetary gears carry the reputation for quality and reliability for which Harmonic Drive® products are known throughout the world.

High torque HPGP and standard torque HPG Quick Connect® gearheads offer high precision and low backlash (standard: < 3-arc-min, optional: <1 arc-min). Harmonic Planetary® HPG gearheads are also available with helical gearing and low reduction ratios. The new models, HPG-R, offer low-speed ratios from 3:1 through 10:1 including all integer ratios in between. Two stage ratios are currently offered in HPG standard and HPGP gearheads, and will be available soon for the new HPG-R. HPG standard torque gear is also available in three sizes as a right-angle configuration for use when space is limited. Innovative ring gear ensures consistent, low backlash for the life of the gearhead.

The HPF Harmonic Planetary® gear unit delivers high-torque and high-accuracy with a hollow shaft design. The gearhead incorporates continuous backlash compensation that ensures low backlash throughout the life of the gear. An extra-large cross roller bearing serves as the output flange and can directly support large loads with exceptionally high moment stiffness. The large coaxial hollow shaft allows cables, shafts, ball screws or lasers to pass directly through the axis of rotation.

Harmonic Drive LLC has a dedicated website for its Harmonic Planetary® gearheads, offering users a quick and easy way to choose the best product for their application. Developed with the design engineer in mind, the website features a robust product selector tool, PDF and DXF drawings, as well as downloadable 3-D solid models. The Product Selector Tool enables the design engineer to quickly filter through Harmonic Drive product specifications to find the right gearhead to connect to their servomotor.

Electromate is the exclusive Canadian distributor of Harmonic Drive products (except the Province of Alberta)

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Servo Mount Gearheads Low Backlash For Life!

HPN Harmonic Planetary® value series provides a low cost solution without the need to compromise on quality or performance. This new value series of planetary gears carry the reputation for quality and reliability for which Harmonic Drive® products are known throughout the world.

- Helical Gearing
- Available in 5 frame sizes
- Peak Torque: 9Nm to 752Nm
- Ratios: 3:1 to 31:1, new two-stage ratios available soon
- Quick Connect® mounting system
- High Efficiency
- Backlash: <5 arc-min (single stage), <7 arc-min (two stage)
- Fast Delivery
- Shaft output available with key and center-tapped hole or with center-tapped hole

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Partners in Precision

State of the Art – the next Generation NEMA23 Integrated Stepper Motors

Birkerød, Denmark - JVL Industri Elektronik A/S, one of the world's leading producers in the field of integrated servo and stepper motors, proudly announces a completely new generation of the NEMA23 integrated stepper motors that have proved their value for many years.

The new motor family, ServoStep, uses the newest technology and the advancement of the previous designs, incorporating customers' feedback. The family has the widest pallet of options in the market and will thus fit into all possible customer applications.

Key features

First of all, integrated motors mean you get an all-in-one solution. In one unit you get motor, drive electronics, encoder, motion controller and an easily programmed embedded PLC with 8 I/O points onboard. The motors can operate as standalone units or be controlled from a master PLC or PC. The 8 I/O points can be individually configured as digital inputs, digital outputs or analog inputs.

Even without options the new ServoStep motors offer some very strong features like closed-loop operation, torque control, ultra-high resolution of 409600 step/revolution resulting in unsurpassed smoothness and silent running plus a wide speed range from 0-3000 RPM with an extreme resolution of just 0.01 RPM.

Power supply goes from 7 to 72 Volt DC and there are 4 pcs M12 industrial connectors for supply, signals and communications. Serial RS485 interface is standard on all motors.

The family base line consists of high torque motors but if even more is needed JVL offers ultra high torque motors with up to 30% higher torque. There are ten different motors with 0.97 Nm to 3.1 Nm.

Popular options include: Absolute multiturn encoders, CANopen, double shaft, hollow shaft, electromechanical brakes (front or rear mounted), better IP protection class up to IP65, special customized connectors and Safe Torque Off (STO) input. Even wireless options exist: Bluetooth, Zigbee and WLAN – ideal for AGVs and other battery supplied applications.

Ready for Industry 4.0 and IIoT (Industrial IoT)

All ServoStep motors can be delivered with industrial Ethernet onboard. You can choose among all major protocols: Profinet, EtherNet/IP, EtherCAT, Sercos III, Powerlink and ModbusTCP/UDP.

No matter which Ethernet protocol were chosen for the machine or the whole factory the ServoStep motors can be connected.

Cabeling is a hassle? Using the onboard Ethernet-switch you can daisy-chain cables from one motor to the next. Quite uniquely on the market, users can even change Ethernet protocol by updating the firmware using the MacTalk software.

Read more about the motors HERE.

For further information, please contact:

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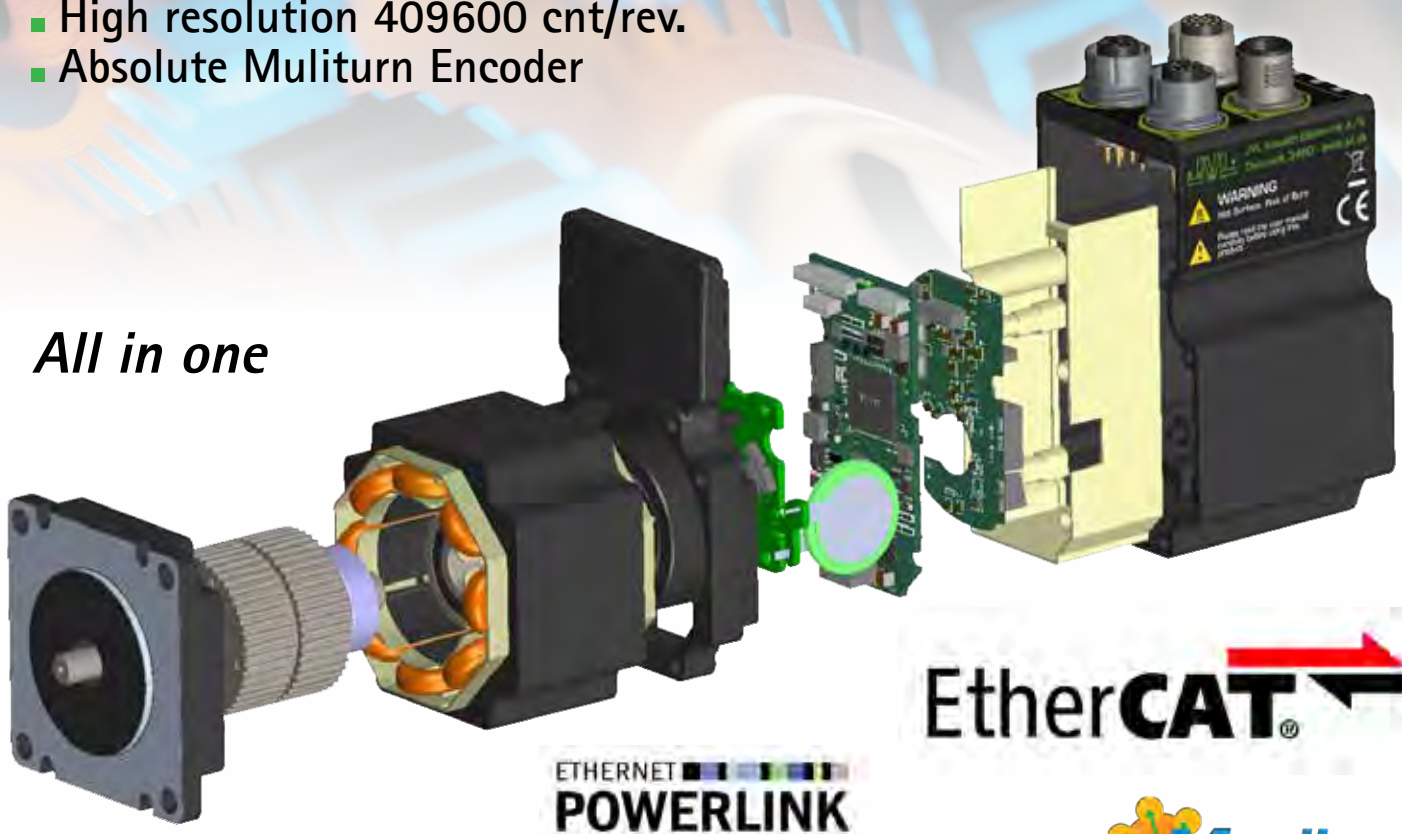
Integrated ServoStep motors

Closed-loop motor with driver, PLC and Ethernet

- NEMA 17-23-34-43 (0,15 to 25 Nm)
- High resolution 409600 cnt/rev.
- Absolute Muliturn Encoder



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Do More with Less: The Next Generation of High-Performance Servo Motors Offers the Opportunity for a Smaller Machine and Increased Productivity

Kollmorgen introduces their new generation of synchronous servo motors, AKM®2G, the latest evolution of the industry-leading AKM® motor product family. With average continuous torque increases of 30%, OEMs and users can achieve substantial machine performance increases without increasing the size of the motor. The improved torque density also provides a smaller motor which reduces the machine footprint without sacrificing performance. Kollmorgen's AKM2G enables machine innovation and productivity advancements in several ways:

Smaller motor → Reduced machine size

AKM2G has average continuous torque increases of 30%, so the space dedicated to motors and mechanical components can be substantially reduced. Space is money – reduction in machine size means a reduction in machine footprint freeing up space for additional production capacity. Smaller, more productive equipment is easier to manage visually and lets operators run multiple machines at the same time, increasing employee productivity.

Increased torque → Existing machines can do more

More performance in the same package size means that existing machines process more. With performance levels between 0.3 and 10 kW, a more powerful AKM2G means that existing machines can produce new product variants such as a new, larger-size product on an existing line, or heavier, increased distribution packaging to improve logistics and product transport.

Wider speed range

The wide speed range of the AKM2G means that existing machines can run faster, change-over quicker and produce more. With rated speeds up to 8,000 RPM, the AKM2G motor enables machines to run faster when product demands surge – both in volume and product mix – which means a faster, more productive factory.

Greater flexibility → Options to machine needs

Kollmorgen understands that the right machine configuration can reduce design, build, operation and service complexity. Connectivity, on both a system and component level, is critical –providing solutions for the complete machine while being flexible enough to connect to current system configurations. Kollmorgen offers more choices to fit mechanical and performance needs – from machine mounts to winding options for the best torque and speed matching, feedbacks, connectors, seals, and thermal protection for drive compatibility, – Kollmorgen provides options to make systems design and build easier.

Higher efficiency → Reduce energy consumption

Energy efficiency is quickly becoming a requirement in multiple markets, making Kollmorgen Servo Motors an ideal choice. AKM2G increases the energy efficiency of an already industry-leading servo motor, AKM, – bringing models to as much as 98% efficient.

About Kollmorgen

Since its founding in 1916, Kollmorgen's innovative solutions have brought big ideas to life, kept the world safer, and improved peoples' lives. Today, its world-class knowledge of motion systems and components, industry-leading quality, and deep expertise in linking and integrating standard and custom products continually delivers breakthrough motion solutions that are unmatched in performance, reliability, and ease-of-use. This gives machine builders around the world an irrefutable marketplace advantage and provides their customers with ultimate peace-of-mind.

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LAFERT NORTHAMERICA

Lafert NA brings you the finest in Italian manufactured IEC metric motors.

We have supplied Metric Motors to the North American market since 1989, providing an extensive range of quality products with exceptional service. If you're designing a system for the North American market or with a global platform in mind, the value of our IEC design motors is immeasurable, making Lafert North America your best source for Metric Motors.

What level of performance do you require from your IEC motor?

AMPH IE3/EISA Premium Efficiency Motors

AC motors have a significant impact on the total energy operation cost for industrial, institutional and commercial buildings. Lafert embraced the challenges and brought a combination of IE3 Premium Efficiency in a high reliability product to service this market.

Customization is key; we can meet the most challenging design requirements you can come up with.

Frame Sizes: 80 – 315
Power: 0.75 – 150 kW
Poles: 2, 4 & 6

HPS IE4 Super Premium Efficiency Motors

The future is now. Lafert has an innovative range of High Performance Permanent Magnet Motors, achieving IE4 & IE5 Super Premium Efficiency levels, offering enhanced efficiency while maintaining reduced operating costs.

HPS series permanent magnet (PM) synchronous AC motors are reduced in size and weight by up to 50%, when compared to a standard induction motor. The HP Standalone series combines the mechanical design of the standard induction motor with the high performance and energy efficiency of the brushless servo motor design, resulting in the development of a compact; robust and efficient motor.

Applications requiring variable speed capabilities with increased efficiencies and an overall savings in operating costs are ideal for the HPS Series. The motors deliver significant energy savings (up to 14%) when compared to EISA Premium AC motors. The performance levels of HPS Series motors allows equipment manufacturers to exceed minimum energy performance standards (MEPS) while reducing ownership costs.

HPI version available with integrated motor and Drive for special OEM applications.

Frame Sizes: 71, 90, 112 - 160
Voltages: 3 phases 230 or 460V
Speed: up to 4500 rpm

Servo Motors

Lafert, the industry-leading expert in production and design of permanent magnet motor technology has its foundation in twenty-five years of brushless servo motor manufacturing. The complete range of AC servo motors are manufactured with an application oriented approach, at our Italian facility and have the flexibility to provide solutions for the customers unique specifications, for applications such as textile, laser cutting, welding machines, robots, packaging, glass (cold end) and injection molding. The "pancake" design allows for direction-drive applications with high torque or low speed.

Our high overload, dynamic performance and power dense servomotors' range is one of the most complete ranges available on the market, with torques from 0.2 Nm to 390 Nm, spread in 14 different motor series and are all UL certified. Direct Drive motors cover torques from 10 Nm to 500 Nm in three (additional) motor sizes and have a wide range of capabilities to match both in European and Asian mechanical designs. The full range is available with ATEX Certification – Zone 2-22, with speeds ranging from 0 – 6000 rpm.

In the last year, five new motor series have been added into the range, with an outstanding compact design. All servo motors are available with a brake execution as an option and are IP65 protected, with TENV construction. Forced ventilation fan cooling option is also available. There is a wide range of transducers available such as sensorless or with resolver, absolute or incremental encoder, or synchro. Lafert can also provide replacement support for current and legacy brushless servo motors.

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maxon motor

driven by precision

maxon drives set the world in motion

The maxon motor combines electric motors, gears and DC motor controls into high-precision, intelligent drive systems that can be custom-made to fit the specific needs of customer applications. maxon motor helps provide innovative solutions at competitive prices for numerous applications in various markets, such as industrial automation, medical technology, security technology, instrumentation, communications, and consumer applications, among others.

Offering solutions that fit your customized needs

maxon motors manufactures small, high-quality brush and brushless DC motors ranging in size from 4 mm to 90 mm. maxon's rhombic wound ironless rotor motors provide exceptionally high efficiency, low EMI emissions, fast acceleration, no preferred rotor position, torque constants and long service life. The drive components are assembled and designed within our modular system according to your individual needs. You can combine, according to your requirements, motors with 10 different product classes with planetary, standard or special gearheads, feedback devices, brakes and control electronics.

Brushed and brushless configurable DC motors - more versions, more power

Now even stronger, more efficient and with yet more combination options: There are new additions to the maxon family of X drive products. Several long versions of brushed DC motors, with higher torques and more power, have been added to the product range along with matching planetary gearheads. Each of the 3-stage versions can now be combined with the next smaller motor. This saves space, weight and costs.

In addition, maxon launched a brushless DC motor (ECX) line to its configurable online program. These motors are available with diameters of 8, 16 and 19 mm achieving

speeds of up to 120,000 rpm. They run very smoothly and are highly efficient in standard or sterilizable versions (up to 2,000 autoclave cycles). Ideal for use in hand-held surgical tools and industrial spindles.

maxon motor's X drives are extremely powerful and are now available in maxon's online shop, where customizing the drives is easy. Customers can fit the drives with specific mechanical and electrical components specific to their application needs. It is possible to customize the shaft lengths, winding types, ball bearings and much more. When combined together with maxon encoders and planetary gearheads, you form a high-precision, robust drive system ideal for any application from aerospace to medical to robotics. In fact anywhere that requires a compact, powerful, quiet and strong drive system.

The X program is a lean and automated process which ensures that all configurable drives are ready for shipment within 11 working days. In addition, detailed product data may be viewed immediately online and 3D CAD data for the configuration is available for downloading. Visit dcx.maxon-motor.com for more information.

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POSITAL
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Built to Meet Your Unique Requirements

Motion control systems come in all shapes and sizes. Getting exactly the right component for each system can be a challenge. At POSITAL, we take pride in providing our customers with the rotary encoders, inclinometers and linear position sensors that are exactly right for their applications.

POSITAL sensors are based on a modular architecture. Individual products are assembled on an as-needed basis from standard components and sub-assemblies to meet each customer's requirements in terms of performance characteristics, mechanical features and communications interfaces. This approach, which POSITAL refers to as "mass customization", makes it possible for customers to receive products that are tailored to their specific requirements. Add in quick delivery times and prices comparable to standardized mass-produced items and you can see that POSITAL sensors are the right choice.

Putting the customer in control

POSITAL's web-based Product Finder tool provides access to over a million possible product configurations. Accessible through www.posital.com, this tool enables customers to browse through the full range of options and choose the configuration that is right for their job. The Product Finder system provides model numbers, specification datasheets and CAD drawings in 11 different languages. Once a product has been ordered, fulfillment usually occurs within a week.

Programmable Performance

POSITAL's new programmable incremental rotary encoders take versatility to a new level. Resolution can be set anywhere from one to 16,384 pulses per turn in software, without changing the mechanical properties of the devices. Pulse direction and the output driver can also be modified through software.

Quality Accessories

POSITAL supplies accessories that make using the company's products easier and more efficient. These include special mounting devices, shaft couplers and POSITAL's easy-to-use UBIFAST programming tool.

POSITAL products are covered with a 3-year warranty.

POSITAL-FRABA CEO Christian Leeser describes the advanced manufacturing system behind these new-generation sensors.

LINK TO VIDEO

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How Smart is your Screwdriver?

By John Miewald

Most consumer goods are assembled with small screws by hand. This close hand-eye work is prone to error. SMAC Moving Coil Actuators, out of Carlsbad, California, has come up with a solution that removes human error and replaces fallible pneumatic screwdrivers with what they call the "Smart Screwdriver."

Using a pneumatic handheld auto-feed screwdriver to install screws is dramatically more productive than manually picking up a screw, inserting it into a part, and driving it home, but simple pneumatic screwdrivers are not an ideal solution either. Workers using pneumatic tools with compressed air and dials to estimate the amount of torque for the screw can strip or misalign the threads if an incorrect torque or angle is used.

For some manufacturers, a misaligned critical screw could result in stopping an assembly line. There is little or no feedback on the work until the device goes to QA. If QA misses the critical screw, it could lead to faulty products, angry customers, and the one word no manufacturer wants to hear- particularly in the automotive and aerospace industries: recalls. When you add this all up, a small screw could cost big money.

A common problem with screws and lug nuts is cross-threading. Cross-threading means the threads on a lug nut or screw are not aligned with the threads on the stud when you start to screw them together. To avoid cross-threading, many assemblers will start lug nuts or screws by hand, turning the screw the wrong way until he feels a bump and hears a sound. This is the screw falling into position. The assembler would then turn the screw several rotations before using a wrench or screwdriver to "snug" it into place. Up until now, this process has been difficult to automate, performed by human operators only.

This is how the Smart Screwdriver automates the process. First, it performs a fast approach, then finds the surface with our patented Soft-Land capability. Then, it turns counter clock-wise and the screw moves up and drops as the first thread is found. This is, in effect, "thread matching" and prevents cross-threading. The linear rotary actuator then starts rotating clock-wise. A "snug" torque can be applied. This is useful when there are a number of screws holding a part on the clamping surface and they need to be snugged evenly, then a final torque is applied. The entire time, the Smart Screwdriver is monitoring the torque and pitch verification. Good, shallow, cross/no-threads, and the precision of the thread are detected through feedback of positon & torque off both axes.

The SMAC Smart Screwdriver performs the same work as a pneumatic auto-feed tool electronically. There is no compressed air, no mechanical parts, and no need for oil or recalibration. On top of being maintenance free the Smart Screwdriver also has a high degree of programmability, so that you know the screw is correctly inserted, when linear height, degrees of rotation and the desired torque have been reached. The smart screwdriver monitors the linear position and force, rotary torque and degree of rotation while simultaneously driving the screw. These parameters are all completely programmable with the capability to have feedback sent to a PLC or database in real time. This ability to perform work and verify all in one move eliminates the need for down the line quality checks that are costly and time consuming.

The SMAC Smart Screwdriver is intended for a wide range of screw sizes, including but not limited to 1.4 millimeter or less, like those found in watches, eyeglasses, cameras, consumer electronics, cell phones, power tools, etc. SMAC Moving Coil Actuators tend to be small but the Smart Screwdriver is so small that it could be attached to a larger robotic arm for special applications, providing 100% quality every time.

Of course, the reverse could also be done. The Smart Screwdriver could be used to automatically disassemble a device, quickly, efficiently, and carefully.

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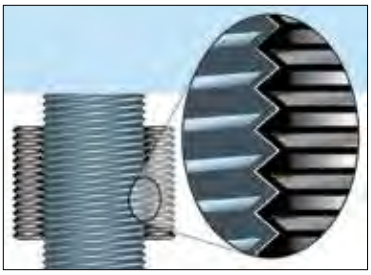
Ball Screw or Roller Screw Electric Actuators:
Selecting the right actuator to replace hydraulic cylinders.

Hydraulic cylinders, known for their high force at an affordable cost, have been widely used in factory automation equipment and other special automation equipment for decades. Hydraulics are rugged, relatively simple to deploy and provide a low cost per unit of force. The electric counterpart, electric rod actuator (cylinders), have become more flexible, precise and reliable with increasingly larger force capacities. In addition, electric actuators offer performance benefits, lower maintenance requirements, no contamination, higher efficiency, better motion control, quiet operation and in many cases a lower cost of ownership.

If ready to consider an alternative technology to hydraulics, the choice turns to either a ball screw or roller screw driven electric actuator. The following comparison is between the ball screw and roller screw with respect to life, load, footprint and other factors.

Roller screws (also called planetary roller screws) have triangular-shaped, precision-ground threads that match multiple precision-ground threaded rollers in the nut. These rolling elements transmit force very effectively. Roller screw components are designed with a fine pitch, providing more points of contact and a larger contact radius. The result is less stress per point of contact.



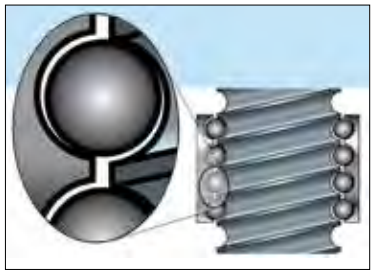
Roller screws have very high force transmission capabilities since the rollers have significant contact with the screw threads. They can deliver high force, operate at high speeds, are long-lasting and require little maintenance.

The use of planetary roller screws is allowing engineers to specify electric actuators in applications that were once the sole province of hydraulic cylinders.

Tolomatic manufactures standard roller screws for its electric actuators. These screws are case (surface) hardened before precision grinding, resulting in very deep case hardness and high Dynamic Load Rating (DLR).

Ball screws get their name from the re-circulating ball bearings that fit between arch-shaped screw threads and corresponding threads in the nut. The ball bearings transmit force and relative motion efficiently as they roll through one or more circuits in the nut.

Ball screw actuators have higher thrust capabilities, longer service lives and higher efficiency than those with acme screw systems, but they can't match the performance of roller screw actuators. Ball screw actuators can be back-driven and can be noisy. They're ideal for applications that require high duty cycles, moderately high thrust and moderate speeds. They tend to be reasonably priced, making them popular in many applications.



When it comes to comparing roller screw vs ball screw of similar size and lead, a ball screw's ball bearings have fewer points of contact than roller screws as shown in the diagram below.

These fewer points of contact, plus a design that allows the bearings to contact each other, limits the ball screw's dynamic load rating, leading to lower force capabilities and shorter life.

For most applications that require high force, repetitive cycles and long expected life, Tolomatic will recommend a roller screw linear actuator. In some cases, high force applications can be solved with a ball screw but require larger actuators. However, if the force is lower, and high continuous speeds are present in the application, Tolomatic may recommend a ball screw actuator.

To learn more download Tolomatic's White paper:

High-force linear motion: How to convert from hydraulic cylinders to electric actuators and why.

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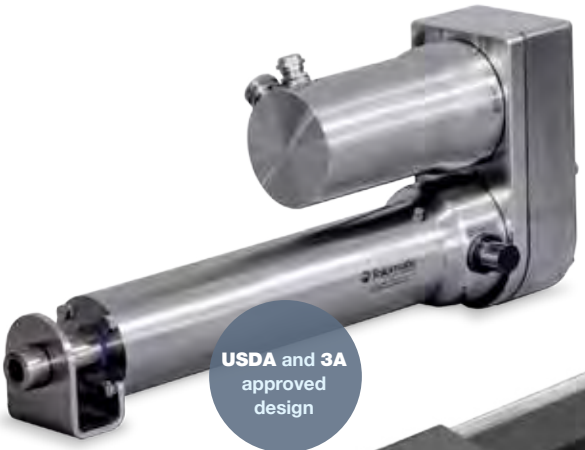

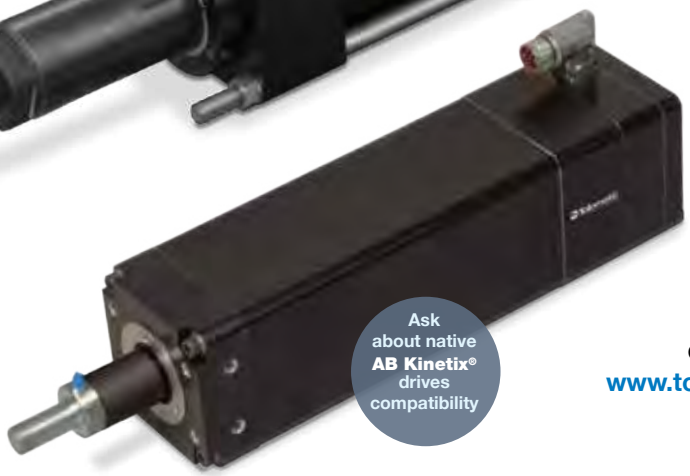

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MOTION MADNESS: A BRIEF HISTORY OF MOTION CONTROL

Take a walk down memory lane and revisit the evolution of motion control systems

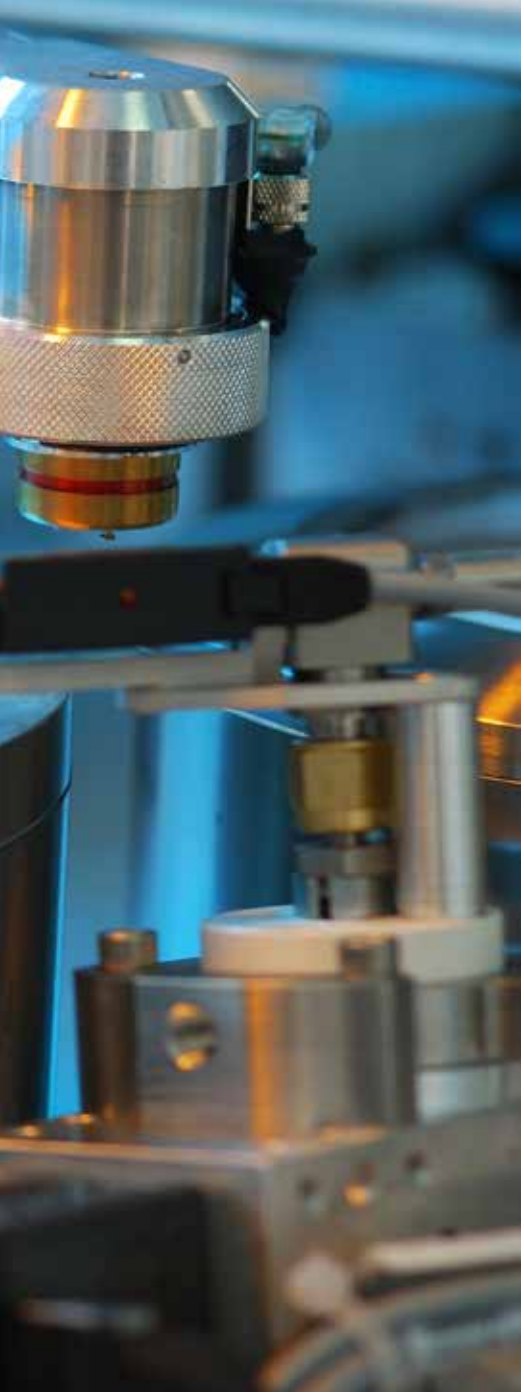
BY DICK MORLEY

In circa 400 BC, Socrates held court in ancient Athens. Socrates himself left no written history, but many of his students have, and some have influence today. Zeno of Elia comes to mind.

Zeno proposed that you could never get to the other side of a room. In a simple format, he suggested that an infinite number of steps would have to be required in a finite time. Going halfway would accomplish exactly that — going halfway. Each time you restart the journey, you only divide the future distance in half.

Modern computer software is now being offered utilizing the Zeno Paradox. In this case, we try to do a culpably infinite number of steps performed in a finite time. This is a "super task." We need to think calculus when we implement physical systems. Zeno helps me rethink control systems using his early calculus concepts.

I assume the reader is acquainted with standard off-the-shelf thinking for motion control. Today, most us use control systems centred around the proportional-integration-differential (PID) loop. I will also assume the reader knows about the PID loop, standards and the simplistic control loops offered today. This column



We grew into the technology of servos, linear sensors, optical digital encoders, pneumatic and hydraulic actuators, and even printed circuit motors.

will be an expansion of this platform.

One of the early speed controls was invented by Watts. It consisted of a weighted system and the axially mounted weights. Rotation would throw the weights out from the vertical axis. Doing so would raise the platform along the axis of rotation. The steam input was controlled by a hit-miss (on-off) method.

In my younger days, I lived in Astoria, Long Island. My home was heated by kerosene and cooled by delivered ice. The ice truck had an internal combustion hit-miss control system. We loved to listen to the idling motor. The engine would run and speed up. The local controller would say "too fast." This would shut the engine off and prohibit ignition. The engine and its large flywheel would then slow down enough to reignite. Hit-miss has a nice rhythm. As an aside, communications were different in those days. To order the ice, we put a rectangular card in the window. It had four numbers around the circumference of the card. The top number told the driver how much ice needed to be delivered today. Ice communication? My good friend, Dr. Wiki, describes all of these references, including Zeno, on the World Wide Web.

In my youth, I helped pay for my college education by being a machinist. In the early 1950s, N.C. was coming of age. Coupling my machinist and physics backgrounds allowed me to design early lathe applications. We grew into the technology of servos, linear sensors, optical digital encoders, pneumatic and hydraulic actuators, and even printed circuit motors.

We learned a lot. Our fundamental tool was a ball screw driven by a husky DC drive. To increase accuracy, we would use off-the-shelf ball screws and measure their inaccuracies. These measurements surveyed pitch and rotational error. Compensation for these errors was done in the software. We also fixed errors due to tool mounting and warpage of the machine base. We compensated for heat expansion. Accuracy and reliability improved our customer's ability to have an unfair market advantage. We talked about a rubber machine tool with full compensation.

There is more to life than the PID of optimization. A ball screw is a hardened metal surface between the screw and the ball. High forces that microscopically damage the two services in contact can damage ball screws. High forces are products of continued differentiation. Position, velocity, acceleration, jerk and more. The ones on the other side of acceleration are sometimes humorously called "snap, crackle and pop." No place on the curve of position displacement should have any sharp edges. These edges damage the ball screw.

For a lathe, never stop at exactly the same spot. Random stop positions improve the life and performance of the screw and ball relationship. A rapid transit to a cutting position need not always stop at the same point. This brinelling (denting of the surface) can occur even without rotary motion. Early automobiles had front-end bearing problems from the jostling of the railroad. It took awhile for the manufacturers of automobiles to understand the problem, and even longer to find a solution.

We found out that there is a big difference between horsepower, torque and speed. We would usually specify a motor without a transmission; usually an error. We needed very high torque at low speeds and almost no torque at high speeds. In large transfer lines, this requirement (at least in history) was with two motors. Each would be geared for optimum performance traversing or cutting. A clutch would choose whether to use the traverse motor or the drilling motor. We could never find an adequate mechanism to do this without a mechanical clutch. As a result, the motor was oversized and heavy. Today, modern rare earth materials and sophisticated solid-state controls can take advantage of these advanced motors.

Designing software and motion control systems is more than the application of simple algorithms. It is the understanding of the problem and the environment. Remember, no sharp edges in the motion profile, and use modern controls and electric actuators. Some of this discussion is applicable to hydraulic systems as well. Eventually, all motion will be run by magnetic forces. After all, these electromagnetic forces and gravity are all that is needed to control our nearby star — the sun.

After reading this, take two aspirin and call me in the morning. | **MA**

Dick Morley is the inventor of the PLC, an author, speaker, automation industry maverick and a self-proclaimed ubergeek.

SYSTEMATIC SELECTION

An overview of the most popular rotary motion technologies

BY DAVID R. BICKERT

The ability to provide accurate rotary motion is critical in a wide range of applications in the automation equipment, medical device, machine tool, energy, welding, robotics, automotive, aerospace, semiconductor and heavy equipment industries along with many others.

Some of the key rotary motion technologies available to address these applications include belt drives, cam indexers, planetary gearheads, direct drives and precision ring drives. It's important to look carefully at the pluses and minuses of each of these technologies in order to ensure that you select the approach that provides the right mix of accuracy, economy, durability, speed, noise, etc., for each specific application. A systematic selection and application process can help ensure that the rotary motion technology that is selected meets all requirements of the application while maximizing the performance and minimizing the cost of this critical component.

Belt drives

Belt-driven rotary tables generally offer the advantages of high speed and low cost in rotary positioning applications. Belts are typically made of fiber-reinforced elastomer and contain teeth that interface with rotor pulleys to efficiently transfer torque and prevent slipping. Typical belt-driven tables offer speeds up to 1,000 rpm, continuous torque to 6.6 N-m and resolution down to 0.16 arc-second using ring encoders. Additional advantages of belt-driven systems include the fact that they generate relatively little noise and require relatively little maintenance. Due to the potential for elongation of the belt, positioning accuracy of belt drives is often inferior to other alternatives, such as planetary gearheads or precision ring drives. In summary, belt drives are a good choice for applications that require high speed and low cost, however, offer relatively poor life and limited load capacity, accuracy and rigidity.

Cam indexers

Cam indexers have been used in rotary positioning applications for many years and are frequently used in dial machines, conveyors and linkages. There are two types of cam indexers. The most common is the fixed index cam indexer, which does not use a servo motor. With fixed index cam indexing, a mathematical motion curve is machined into the cam to provide accurate positioning to a discrete number of defined positions. During rotation of the cam indexer, maximum displacement velocity usually occurs around the midpoint of the index cycle. Any fluctuation in cam speed tends to generate increased output torque at the high displacement portion of the cycle. These torque fluctuations sometimes generate irregular rotary motion during indexing, as well as audible noises when the indexer approaches a station. These problems can be avoided by maintaining shaft speed within a very narrow range. Fixed index cam indexers provide high-precision positioning at a reasonable cost for applications that will always index to the same angle and do not require high acceleration.

Fully programmable cam indexers combine a servo motor with a cam-driven index drive. This type of cam indexer is advantageous when a flexible motion

pattern is required, such as when two different products that require different indexing patterns are run on the same machine. A fully programmable cam indexer is also beneficial for applications where extremely fast positioning is required, followed by a long dwell period.

Planetary gearheads

Planetary gearheads are frequently used on motion control applications that require a high torque to volume ratio. Planetary gearheads utilize an arrangement in which one or several planet gears rotate around a pinion or sun gear. The planet gears rotate within an internal gear that is most often cut into the internal diameter of the gearhead. The planetary gear decreases the reflected load inertia at the motor shaft by the inverse of the square of the gearhead ratio, which increases the control system responsiveness and generally provides more consistent and accurate motion response. The planetary gearhead offers the advantage of a wide range of gear ratios which, in many applications, will make it possible to operate both the motor and the application at their ideal speed. Single-stage planetary gearheads typically provide ratios from 3:1 to 10:1. Helical gearing improves the performance of a planetary gearhead over spur gears by increasing the contact load line. The potential drawbacks of planetary gearheads include their relatively high cost and the fact that they contain backlash and can be damaged by shock loads.

Direct drive

A direct drive rotary motor is typically a large diameter permanent magnet servo motor. The unique characteristic of direct drive rotary positioning systems is that the motor is connected directly to the load eliminating all mechanical transmission components. Rotary positioning systems built around direct drive rotary motors are wide used in the factory automation, medical equipment and energy industries. Direct drive systems generate energy savings by operating at high levels of efficiency because the elimination of the power transmission system provides a substantial reduction in friction. Direct drive systems also have fewer components, which often reduces maintenance requirements and provides quieter operation because there are few

A systematic selection and application process can help ensure that the rotary motion technology that is selected meets all requirements of the application while maximizing the performance and minimizing the cost of this critical component.

parts that can vibrate. The elimination of the gear train also reduces backlash and compliance. Sometimes a direct drive system is combined with an encoder mounted on the rotary table to provide precision positional feedback and a high stiffness bearing to improve positional accuracy and repeatability, however, this approach is quite expensive relative to other technologies discussed here. While direct drive motors provide high levels of performance and efficiency, they are limited by low load capacity, high cost and relatively low accuracy without costly ring encoders.

Roller pinion systems

The precision ring drive is a somewhat new type of rotary positioning system featuring a unique roller pinion/toothed rack combination that delivers high accuracy positioning with zero backlash and virtually eliminates cumulative error. Precision ring drives at first glance look similar to ring and pinion sets but, instead of spur gear teeth, bearings supported rollers engage the ring teeth. The rollers engage a tooth profile designed to match the pinion's path, providing friction-free meshing that allows the pinion to be pre-loaded into the ring, eliminating mechanical clearance. The rollers approach the tooth face on a tangent path and then smoothly roll down the face. Each tooth is precisely measured relative to the first, eradicating cumulative error and maintaining high positional accuracy. The resulting smooth rolling friction provides 99-per-cent efficient rotary motion. Due to the smooth way the rollers engage the rack teeth, the new approach generates very low noise and vibration. The system is whisper quiet at low speeds and produces less than 75 db noise at full speed.

Drives are offered with ratios ranging from 64:1 to 220:1. Peak torque goes from 563 to 1,936 Nm. Accuracy ranges from ffl11 to ffl35 arc-sec, with repeatability of ffl4.2 to ffl1.2 arc sec. Unlike traditional cam-drive systems, the precision ring drive can start and stop at any incremental position. Users can change the motion profile simply by loading a new servo drive program. The roller pinion system driving the precision ring drive also allows the application of maximum acceleration or deceleration at any point without risking damage. The precision ring drive is capable of speeds up to 300 rpm and can handle peak torque inputs at any time, resulting in index speeds up to two times faster than other types of positioning systems. A given size product in a premium model can support a maximum dynamic load (N) of 1,000. The drive mounts on a table supported by cross-roller bearings rated for 1,575-kN loads. The roller pinion system requires little maintenance. The pinion consists of 10 or 12 needle-bearing supported rollers that are sealed and lubricated for life. The ring is lubricated with a high performance light grease at installation and then every six months or 2 million pinion revolutions; no messy oil baths are required. Pinion life is rated at 60 million revolutions and the pinion gear can usually be replaced numerous times before the ring gear needs replacement. The ring drive has a large open centre that allows users to easily mount equipment and cabling in the centre of the rotating plate.

Conclusion

Rotary motion technologies, such as belt drives, cam indexers, planetary gearheads, direct drive systems and roller pinion systems each offer their own unique mix of advantages and disadvantages. In order to apply the correct type of rotary motion technology in a particular application, the design engineer should carefully consider the specific capabilities of each alternative. Selecting the right technology can improve performance, ensure long life and reduce the overall cost of the assembly. | **MA**

David R. Bickert, regional sales manager for Nexen Group, has more than 24 years of work experience in automation and motion control. He has a bachelor of science (B.Sc.) degree in mechanical engineering technology from Penn State University and an M.B.A. from Fontbonne University. Bickert has worked at Nexen Group for more than 13 years.

LOOKING AHEAD TO AN AUTOMATED FUTURE

What the risk of automation means for the next generation of workers

BY DANIEL KOMESCH

Automation has become a scary word lately. As new technologies proliferate, unease and uncertainty surround the labour market of the future. Will jobs be destroyed? Created? Can a robot really replace what I do? What kind of career should my child pursue if we don't know what the jobs of the future will look like? How can I retrain?

If new studies are to be believed, nearly half of the Canadian labour force is at high risk of automation in the next 10 to 20 years. But what does that really mean for today's — and tomorrow's — workers?

The reshaping of economies due to innovations in technology is a challenge that has persisted across time — in fact, economist Joseph Schumpeter considered it to be the essential fact about capitalism: technologies emerge and economies are forced to transition.

In the face of a transitioning economy, we only have one choice, really:

In the face of a transitioning economy, we only have one choice, really: embrace and adapt. Looking ahead to an automated future, where should Canada concentrate its educational energies?

embrace and adapt. So, looking ahead to an automated future, where should Canada concentrate its educational energies?

The solution should be co-operational, which means tapping all of Canada's resources as we adapt to the needs of the future. So politicians and policy makers would be wise to look beyond the usual players.

One of the avenues forward includes embracing educational institutions that are already used to working hand-in-hand with industry — which means they're already accustomed to perpetual innovation.

I'm talking about polytechnics. Polytechnics are publicly-funded colleges and institutes of technology that offer a full suite of credentials, including four-year bachelor's degrees and apprenticeships, while at the same time offering industry a range of R&D and innovation services. Programs are skills-intensive and technology-based, encompassing hands-on and experiential learning.

Polytechnics already have tight connections to Canadian industry, built through their innovation services and advisory groups made up of industry representatives, so they tend to know where labour markets are headed and care about the skills that are necessary for the jobs of today and tomorrow.

For example, Humber College, Ont., in Toronto deployed its Electromechanical Engineering – Automation and Robotics Advanced Diploma program in response to a manufacturing sector that has faced technological disruption. This program develops skills in industrial automation, robotics, control systems, machining, hydraulics, pneumatics, mechatronics and automated welding.

Calvin Kimura graduated from the program in 2013 and after first working as a robotics technician at global manufacturing giant Magna, he now owns and operates CK Automation, which supplies business with a suite of automation services from design, development, build, installation and maintenance.

That's how innovation and job growth happens. And it didn't come from the lab, but from a polytechnic education aligned with industry needs.

Yet polytechnics are often neglected by policy makers. Their sister-institutions, universities, get the policy limelight. But as many as 30 per cent of students attending a polytechnic have previously attended university. That number is on the rise.

Why? Polytechnics are particularly good at a key component: connecting the supply and demand sides of the labour market. This is especially valuable as new technologies emerge that require the adoption of new skill sets.

One way polytechnics anticipate labour market shifts is through their Program Advisory Committees, comprised in part of industry leaders.

Mike Cybulski, director of business development at RAMP Inc., another automation powerhouse, has served on Conestoga College's Program Advisory Committee for the Advanced Diploma in Mechanical Engineering Technology in Kitchener, Ont. Cybulski advised instructors on how to design their curricula so that graduates are immediately employable in the field. RAMP itself employs approximately 30 Conestoga College graduates — certified technologists and tradespeople.

Advisors like Cybulski emphasize the need for polytechnics to offer a broad swath of credentials and to grow multidisciplinary talent — both necessary for an innovation or automation economy.

If the essential fact about capitalism is creative destruction and the necessary reshaping of economies, then governments need to see polytechnics as the economic actors they are and bring them into the innovation policy discussion. Polytechnics adapt, embrace, and thrive in the face of economic challenge and change. Canada is on the verge of becoming an automation nation, and polytechnics say, "bring it on."

If we are to harness all the talent we have available, it is time Canada's policy makers caught up and recognized the important place of polytechnics in the full suite of educational opportunities available to all Canadians. | **MA**

Daniel Komesch is a senior policy analyst with Polytechnics Canada.

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