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SERVO ADVANCES

LEAD THE MOTION CONTROL REVOLUTION 8

MARCH/APRIL 2024 machinedesign.com

The TRUTH About COMPRESSED AIR!

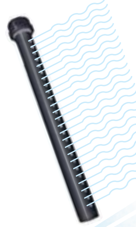
If you think compressed air is too expensive and noisy - read this. The facts will surprise you!

Compare These Blowoffs

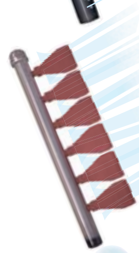
There are a variety of ways to dry, clean or cool products and surfaces, but which method is best? To decide, we ran a comparison test on the same application using four different blowoff methods: drilled pipe, flat air nozzles, Super Air Knife (each using compressed air as a power source), and a blower supplied air knife (using an electric motor as a power source). Each system consisted of two twelve inch long air knives.

The following comparison proves that the EXAIR Super Air Knife is the best choice for your blowoff, cooling or drying application.

The goal for each of the blowoff choices was to use the least amount of air possible to get the job done (lowest energy and noise level). The compressed air pressure required was 60 PSIG. The blower used had a ten horsepower motor and was a centrifugal type blower at 18,000 RPM. The table below summarizes the overall performance.



Drilled Pipe This common blowoff is very inexpensive and easy to make. For this test, we used (2) drilled pipes, each with (25) 1/16" diameter holes on 1/2" centers. The drilled pipe performed poorly. The initial cost of the drilled pipe is overshadowed by its high energy use. The holes are easily blocked and the noise level is excessive. Velocity across the entire length was very inconsistent with spikes of air and numerous dead spots.



Flat Air Nozzles This inexpensive air nozzle was the worst performer. It is available in plastic, aluminum and stainless steel from several manufacturers. The flat air nozzle provides some entrainment, but suffers from many of the same problems as the drilled pipe. Operating cost and noise level are high. For some flat air nozzles the holes can be blocked - an OSHA violation. Velocity was inconsistent with spikes of air.

Blower Air Knife The blower proved to be an expensive, noisy option. As noted below, the purchase price is high. Operating cost was considerably lower than the drilled pipe and flat air nozzle, but was comparable to EXAIR's Super Air Knife. The large blower with its two 3" (8cm) diameter hoses requires significant mounting space. Noise level was high at 90 dBA. There was no option for cycling it on and off to conserve energy. Costly bearing and filter maintenance along with downtime were also negative factors.

EXAIR Super Air Knife The Super Air Knife did an exceptional job of removing moisture on one pass due to the uniformity of the laminar airflow. The sound level was very low. For this application, energy use was slightly higher than the blower but can be less than the blower if cycling on and off is possible. Safe operation is not an issue since the Super Air Knife can not be dead-ended. Maintenance costs are low with no moving parts to wear out.

The Super Air Knife is the low cost way to blowoff, dry, clean and cool.

Blowoff Comparison

Type of blowoff	PSIG	BAR	Comp. Air SCFM	Comp. Air SLPM	Horsepower Required	Sound Level dBA	Purchase Price	Annual Electrical Cost*	Approx. Annual Maintenance Cost	First Year Cost
Drilled Pipes	60	4.1	174	4,924	35	91	$50	$4,508	$920	$5,478
Flat Air Nozzles	60	4.1	257	7,273	51	102	$300	$6,569	$1,450	$8,227
Blower Air Knife	3	0.2	N/A	N/A	10	90	$7,000	$1,288	$1,500	$8,288
Super Air Knife	60	4.1	55	1,557	11	69	$842	$1,417	$300	$2,559

*Based on national average electricity cost of 8.3 cents per kWh. Annual cost reflects 40 hours per week, 52 weeks per year.

Facts about Blowers

Energy conscious plants might think a blower to be a better choice due to its slightly lower electrical consumption compared to a compressor. In reality, a blower is an expensive capital expenditure that requires frequent downtime and costly maintenance of filters, belts and bearings.

Here are some important facts:

- Filters must be replaced every one to three months.
- Belts must be replaced every three to six months.
- Typical bearing replacement is at least once a year at a cost near $1000.

- Blower bearings wear out quickly due to the high speeds (17-20,000 RPM) required to generate effective airflows.
- Poorly designed seals that allow dirt and moisture infiltration and environments above 125°F decrease the one year bearing life.
- Many bearings can not be replaced in the field, resulting in downtime to send the assembly back to the manufacturer.

Blowers take up a lot of space and often produce sound levels that exceed OSHA noise level exposure requirements. Air volume and velocity are often difficult to control since mechanical adjustments are required.

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From the Editor

By **Rehana Begg**, Editor-in-Chief

Motion Control is Not About to Hand the Reins to AI, But...

When it comes to industrial components, engineers shouldn't throw new and novel tech at every problem. Prudence rules.

"THE PATH FROM HERE TO THERE is not built so much on new technology, but new ways of implementing and combining it."

This line, clipped from a *Machine Design* article on the basics of systems engineering harks back to 2001. Should the authors flip through this issue's cover series on motion control technology, they'd say it's déjà vu.

"Functions that now sprawl over two or three components may end up residing in one; some elements may be gone entirely, dissolved into the fabric of the machine or taken up in software," noted Lawrence (Larry) Berardinis and Francis Richards back then.

They would be struck by the veracity of their expectations when they see how a seemingly novel interdisciplinary approach to motion component design has evolved into fully-fledged strategies that transform components—in some cases to the point of being unrecognizable.

Intended as insights into the design of motion system components, their prognostication proved to be relevant today. Recent iterations in axial flux motors support this assertion. Thought to be more expensive to design and manufacture than radial motors, axial flux topology usually presents unavoidable complexities due to positioning of the stator and windings. Now, solutions based on PCB winding topologies for axial-flux machines offer a viable alternative.

In applications where long-travel motion axes and transfer robots are used, moving motors provide another example. Belt drives are usually configured so the motor remains stationary and drives the belt by way of a pinion.

But this setup limits the motion system's performance due to belt sag and varying stiffness along the belt length. The hindrance becomes more pronounced as travel lengths exceed 15 meters, explained contributor Michael Everman ("Moving Motors Stretch the Possibilities of Long-Travel Motion," p. 16).

Similarly, rather than designing a robotic joint from scratch, a design engineer might consider off-the-shelf integrated robotic joint systems. The HPJ joint modules from maxon consist of an EC frameless DT motor, a strain wave gear, a motor encoder, an output absolute encoder, an optional braking device and a high-accuracy position controller board.

New technology advancements are infiltrating legacy components at a rapid clip, too. Endless booth crawls at trade shows and factory visits these past few months have confirmed the occasion is rare where generative AI is not high on the agenda. To be clear, discussions are not about throwing emergent tech at everything. When it comes to industrial components, bringing connectivity to simple devices is seldom about the fraction of data it produces or consumes.

Rather, it's about the ability to extract data from the device on an integrated network and using it to glean actionable results. This is why the demand for dynamic, adaptive design approaches that enable responsive manufacturing practices and support flexibility in production should now be considered the norm, rather than the exception. ■

MachineDesign

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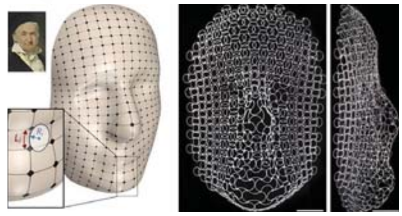
4D Printing: The Next Dimension of Advanced Manufacturing



Researchers envisage 4D printing technology will have significant application potential for healthcare, automotive, aerospace and consumer industries. But what is it exactly?

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A Beginner's Guide to Design Failure Mode and Effects Analysis (DFMEA)

Design Failure Mode and Effects Analysis puts a tool in the back pocket by giving engineers the ability to catch design hiccups before they become a big deal.

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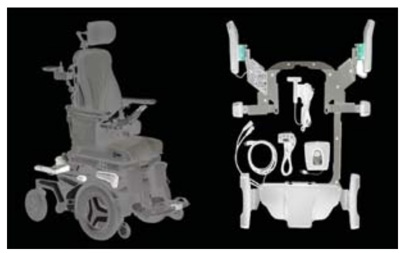
Using Injection Molding to Design a "Smart" Wheelchair Fit for Family



To robustly secure plastic housings for the wheelchair accessory, the part incorporated threaded metal inserts into molded plastic housings to improve strength.

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Featured Video

Manufacturing Software Solutions: Insights on Where the Puck is Going in 2024

Karan Talati, CEO and co-founder of First Resonance, discusses the current trajectory of integrated manufacturing processes and explains how market forces lead the way.

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Distributed Motor Control:
Design Uptime into Component Setup

Rockwell Automation's suite of On-Machine solutions enable easy access to components so personnel can address problems at the source.

THE LATEST ADDITION to Rockwell Automation's On-Machine product portfolio reimagines design and access to control units. The range consists of rugged, compact, plug-and-play automation components that can be field mounted outside of an electrical cabinet, thereby bringing them much closer to the component and achieving new levels of performance with fewer components.

For instance, flexible mounting orientations enable drives to be located closer to the motor, and by extension enable operations and maintenance personnel to increase uptime by troubleshooting at the source.

Rockwell Automation noted that the modular approach has shown benefits to control panel setup by reducing cabling by up to 90% and that by scaling down or eliminating temperature control systems, companies can lower the resources and energy expended in the manufacturing process. On-Machine also supports automation systems in ways that are modular and scalable relative to traditional systems.

"Manufacturers are facing market trends that quickly change and consumers that are demanding more customization and innovation," said Joe Azzolina, senior product manager, Armor PowerFlex, Rockwell Automation. "On-Machine solutions are less constrained by physical boundaries such as enclosure size or ridge architectures. This means that modular design is easier to achieve, and OEMs and end-users alike can be adaptive and build for the future."

The following components are included in the latest offering:

ArmorKinetix Distributed Servo Drives. Provides high-performance of the Kinetix 5700 platform in a compact, IP66/67 rated form factor, configurable as near-motor drive or integrated drive-motor solution.

ArmorBlock 5000 I/O Blocks. Offers ratings up to IP69K, three power variants, flexible mounting options and use IO-Link technology for harsh environments.

Armor PowerFlex Drives. Provides On-Machine VFD motor control solutions that enable more smart, safe, secure and simple operations, featuring gigabit dual-port EtherNet/IP communication with hardware and network safety features.

ASEM 6300PA On-Machine Industrial PCs. Helps save time, space and installation cost. With a fanless design and wide temperature specs, these PCs are built to deliver years of reliable operation.

"On-Machine solutions are less constrained by physical boundaries such as enclosure size or ridge architectures. This means that modular design is easier to achieve, and OEMs and end-users alike can be adaptive and build for the future."

— Joe Azzolina,
Senior Product Manager,
Armor PowerFlex,
Rockwell Automation

Rockwell Automation's On-Machine offering was designed for machine control. The components are suitable for harsh environments and ideal for material handling and conveyor applications. *Courtesy of Rockwell Automation*

Driving Robotics and Embedded Motion Applications with **Next-Generation Servo Technology**

Exploring compact, efficient and powerful nano-type servo drives with innovative thermal management technology and EtherCAT or CANopen support.

by Dean Crumlish,
Product and Applications Manager,
Copley Controls

Courtesy Copley Controls

TO MEET THE NEEDS of today's advanced motion control applications, servo drives are getting smaller. However, the power requirements are far from following suit. These applications require powerful, embedded drives that must function in constrained spaces in order to meet the ever-shrinking size requirements of modern machines. To this end, many miniature servo drives can be mounted onto the motor itself or within robotic joints.

Compact, powerful and embedded servo drives play a particularly important role when it comes to robots, which are increasingly taking center stage across many industries. In healthcare settings, they enable new, state-of-the-art surgical and diagnostic practices. They also play an important role in the semiconductor manufacturing sector for their ability to handle small, delicate parts and complex assemblies with high levels of precision and cleanliness. And in the world of logistics, mobile robots can navigate warehouses and distribution centers autonomously, streamlining operations and accelerating order fulfillment.

Other important industries for embedded servo drives include aerospace, lab automation and biomedical equipment, along with other complex systems that must handle and transport objects, navigate the environment and accomplish various tasks.

Yet for all the innovations happening in the world of automation, the compact servo drives behind these sophisticated systems must be able to meet a combination of requirements related to motion control, size and power, including:

- Providing high positional accuracy and repeatability.
- Achieving excellent dynamic performance, including smooth motion profiles, fast response times, and precise speed and torque control.
- Supporting real-time communication protocols, such as EtherCAT, to ensure reliable communication between the drives and control system.
- Featuring a compact size for mounting onto the motor itself or within the robotic joint.
- Packing enough power, despite their small size, to move the robotic arm, AGV or AMR with the utmost reliability and efficiency.

Meeting all these requirements is easier said than done, however. Designing powerful, miniaturized servo drives that can perform within the tight confines of robotic joints, AGV chassis and other embedded motion control applications presents a number of design challenges—not the least of which is thermal management.

How to Stay Cool

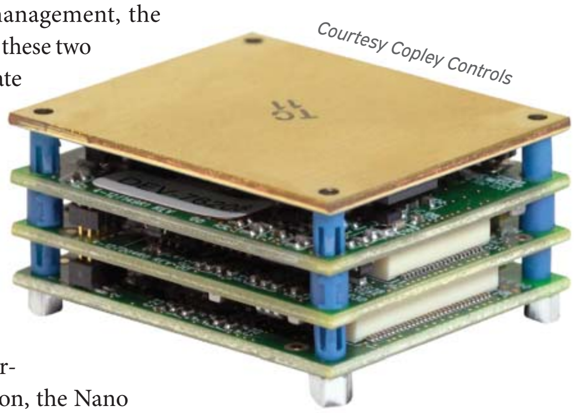
As servo drives shrink in size, the surface area available for heat dissipation shrinks as well, making thermal management progressively more challenging. Fortunately, there are a number of design principles that together can maximize the efficiency of even the smallest embedded drives. Nano embedded servo drives (see sidebar) exemplify these principles to deliver industry-leading power density and efficiency (>99%), which helps with managing heat and electromagnetic interference (EMI), as well as supporting size reduction.

Circuit materials. The first and most obvious heat dissipation solution involves an upgrade to the drive's circuit board materials. The Nano drive, which consists of a four-board PCB stack, uses a single-sided board with a copper-alloy substrate (TClad). This board, which handles power for the device, would traditionally have had an aluminum substrate, but the switch to the proprietary TClad copper alloy resulted in a threefold improvement in thermal conductivity.

Custom components. Another solution involves the use of custom-designed components to increase heat dissipation capabilities. For example, the Nano features custom-designed pins to carry current out of the drive. Not only are the custom pins smaller than a standard connector, but they are also designed to conduct heat away from the drive.

Dynamic gate drive tuning. The output stage consists of two key components—the gate drive integrated circuit (IC) and metal-oxide-semiconductor field-effect transistor (MOSFET)—both of which tend to be standard, off-the-shelf components that are used by all key players in the motor drive world. To maximize the Nano's thermal management capabilities, we make critical design decisions during their selection process:

- **The gate driver IC.** We select compact, half-bridge drivers with high output current capabilities. Because the output current limits the size of the usable output stage MOSFET, it is important that we select drivers with high-current capabilities.
- **The output stage MOSFET.** These components must feature a small package, low thermal resistance, high current and low drain-source on resistance (RDS(on)).


Courtesy Copley Controls

In terms of thermal management, the magic happens in between these two components. Dynamic gate drive tuning controls the timing between the power device turn-on and turn-off to achieve low power dissipation while meeting electromagnetic compatibility (EMC) requirements.

Current sensing. To further reduce heat dissipation, the Nano features some clever methods for measuring current. This novel approach to current sensing uses ultra-low-resistance current sense resistors, enabling precise current sensing with minimal power dissipation.

Finally, the smallest, most powerful servo drives also need to apply a variety of other strategies to minimize heat buildup. In the case of the Nano, these include the overall construction and layout of power components on the board. We can also pull a number of levers within the drive's firmware to further reduce dissipation, if required. For example, one feature—called bus clamping—effectively reduces switching losses by as much as 33%.

At the end of the day, managing the heat on the smallest, most powerful drives does not come down to a single design principle. Instead, it's the sum of many small, carefully considered design decisions. ■

THE NANO SERIES OF DIGITAL SERVO DRIVES

An example of a servo drive that incorporates the right power density and thermal management features is the Nano Series. Each compact unit integrates easily into AGVs, AMRs, robotic joints and other automated equipment. Designed for space-limited applications that need precise speed and position control, the Nano Series represents the next generation of motion control technology, enabling users to achieve unparalleled accuracy and efficiency in their applications.

The Nano Series comes in a small footprint of 35 by 30 by 23.4 millimeters, operates from 9 to 180 VDC input voltage and delivers up to 35A of continuous current and 70A peak current to provide exceptional power density and efficiency. Its compact size also gives integrators the flexibility to mount units directly onto the motor or within robot joints. The optional connectorized PCB and CME commissioning software facilitates setup and tuning.

Additional features and specifications include:

- Safe Torque Off (STO) capability with Sil 3, Category 3, PLe conformance
- Six digital inputs and four digital outputs
- Four voltage and current combinations
- One ±10-volt (V) 12-bit analog input
- BiSS-C unidirectional, SSI absolute encoders and CSR Resolver (primary)
- Digital incremental encoder (primary and secondary)
- Frequency analysis tools
- Dual encoder feedback support
- 32-bit floating point filters and multiple advanced filters

In addition, the Nano Series supports EtherCAT or CANopen communication protocols, enabling real-time data exchange. Nano Module EtherCAT NES and Nano Module CANopen NPS models are available with an EZ Board option to simplify mounting.

Axial Flux Motor Topology Signals Next Generation of Electric Motors

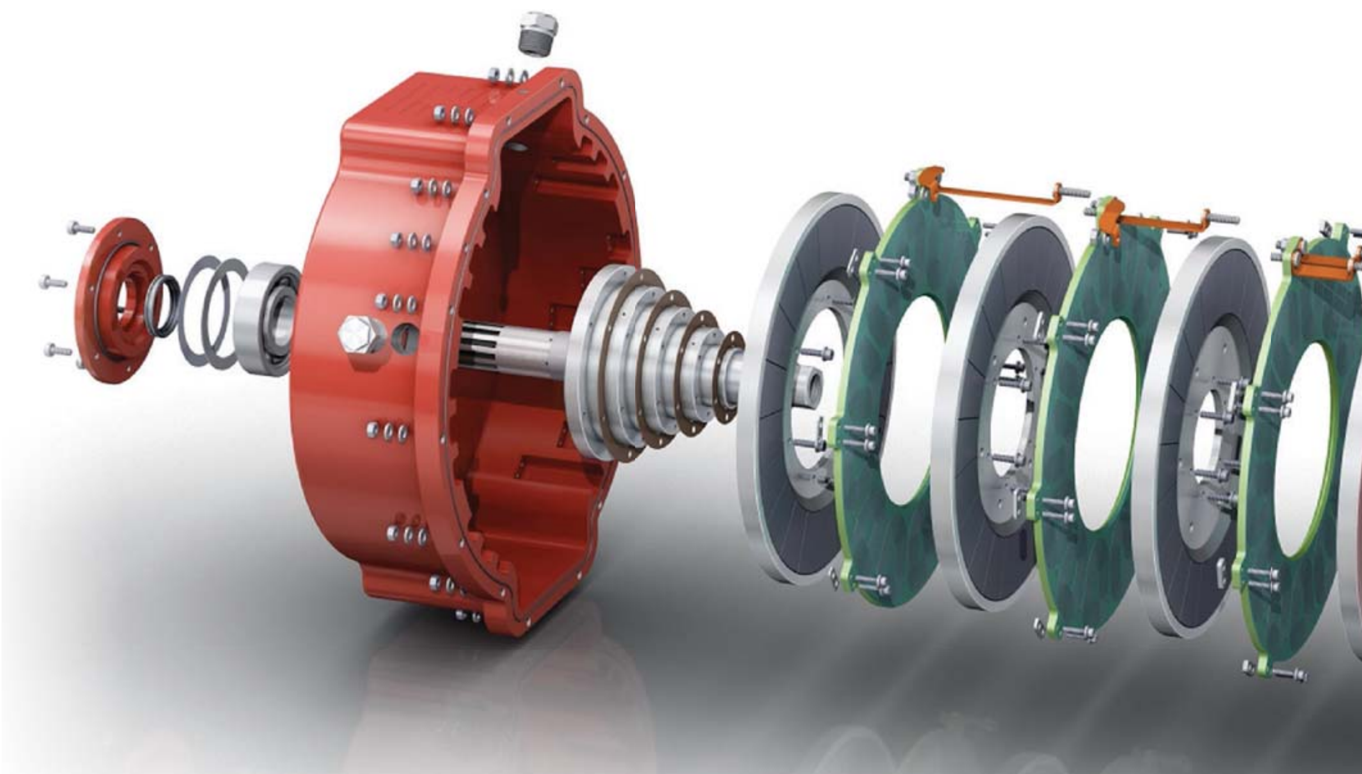
Axial flux propulsion and traction motor design features new levels of power, efficiency and manufacturability. Expect the technology to foster uptake in the HVAC systems market.

by Rehana Begg, Editor-in-Chief

THE USE OF axial flux motors is gaining traction across industries, particularly in the electric motor space.

Axial flux motors or pancake motors are mechanically configured to provide specific advantages when compared to ubiquitous radial flux motors. By design, the space between the rotor and stator (described in technical terms as the direction of magnetic flux between the two) in an axial flux motor is aligned parallel to the axis of rotation.

Its counterpart, the radial flux motor, is named for the magnetic field generated by the stator windings that moves radially across the air gap between the stator and rotor, and induces a torque that turns the rotor. Despite the ubiquity of radial flux motors, both types offer characteristic strengths and weaknesses, depending on the application.



Infinitum's chief strategy officer, Bhavnesh Patel, said the Aircore Mobility motor replaces the heavy, copper wound iron stator found in traditional motors with a lightweight, printed circuit board (PCB) stator that is 10 times more reliable.
Infinitum

According to Infinitum's chief strategy officer, Bhavnesh Patel, axial flux propulsion is gaining ground in the EV space due to specific design form factors that allow the motor to sustainably power passenger and commercial electric vehicles. Axial flux motors, he said, are touted for their ability to generate more torque and power density than radial flux motors, and occupy less space based on the configuration.

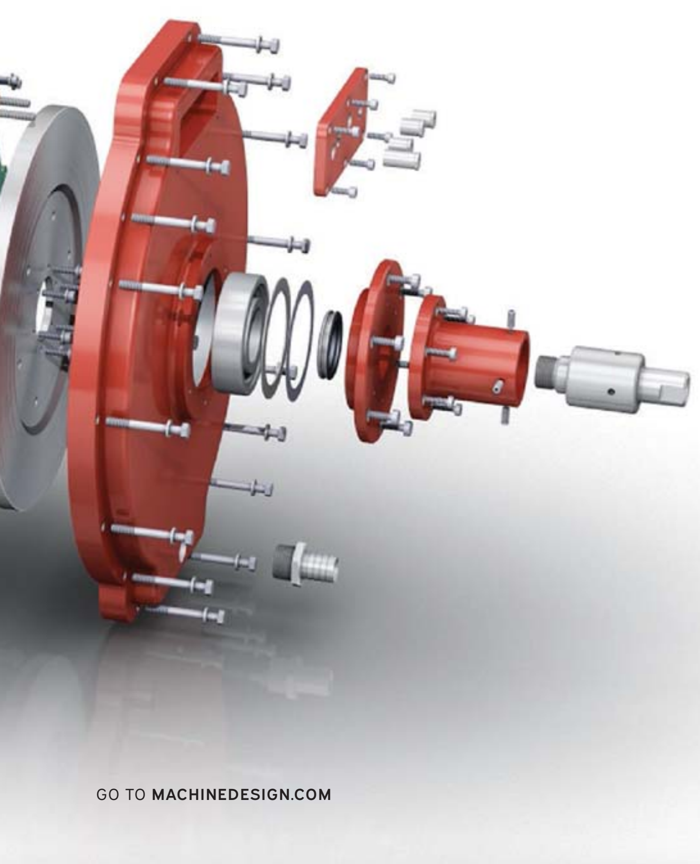
Aircore Motor Topology is Different

Patel told *Machine Design* during a one-on-one briefing that Infinitum would be rolling out the next generation of its axial flux motor (Aircore EC motor) at AHR Expo in Chicago, which took place Jan. 22-24.

Aircore EC is a high-efficiency motor designed to sustainably power commercial and industrial applications—such as HVAC fans, pumps and data centers—with less energy consumption, reduced emissions and reduced waste.

Covered by 43 issued patents and 48 pending patents, the new motor replaces the heavy, copper wound iron stator found in traditional motors with a lightweight, printed circuit board (PCB) stator that is 10 times more reliable, 10% more efficient, and 50% smaller and lighter, noted Infinitum's briefing notes.

Every motor is built around a stator and rotor. "A stator is essentially copper wire wrapped around iron; you can run current through that copper and it creates magnetic field," explained Patel. "The innovation that we have is that we eliminated the iron within that stator and, instead of using copper wire, we



etched the copper on multiple layers of a printed circuit board. And that results in is a number of benefits."

In mobility applications, for example, PCB stators offer promising performance and efficiency benefits due to superior heat mitigation and high power density. Another distinguishing factor is that it uses 66% less copper than conventional motors, Patel said. Replacing the iron core with a PCB stator has further resulted in a reduction in mechanical losses, greater efficiency gains, and noise and vibration reductions.

With the PCB stator design, said Patel, the motor can achieve up to four to five times the current density of a conventional, liquid cooled motor using a liquid cooling technique that allows the coolant to be in direct contact with the stator, mitigating heat across a larger surface area, enabling high overload capability and extended life.

Combination of Motor and VFD

The startup characterized the Aircore EC motor system as an integrated variable frequency drive that delivers upwards of 93% system efficiency, as well as class-leading power and torque density in a low-footprint package that is 20% lighter than the previous version.

The combination motor and variable frequency drive or VFD ("essentially the electronics that drive the motor") is a defining feature. The advantage of combining the two components, according to Patel, is that Infinitum was to "software-define the motor." In other words, through firmware, the OEM can tell the motor exactly what operating point it needs to operate at. (For instance, 10 HP, or 9 HP, or 7 HP, and so forth.)

Motors typically come off the shelf with a NEMA sticker and UL compliance rating. "The UL sticker will say, for example, a 10 HP, 1800 RPM motor will draw 12 amps," explained Patel. But this presents a limitation, he said, because it denotes the only operating point at which one can modulate the speed. "That means that the machine designer or equipment builder will have to make sure their wiring size is designed for 12 amps, that every one of the motors can support 12 amps, that the circuit breakers have to be designed around 12 amps, the transformers and overload relays and everything else upstream has to be designed for 12 amps," Patel said.

But developing a combo solution—motor with the VFD—has meant that the design engineer has more flexibility. "If the customer's operating point is something other than 10 HP—let's say it's a 1,200 RPM application—we can actually tell the motor that its max speed is 1,200 RPM," said Patel. "But the UL sticker reflects that the motor now is drawing a lower input current. So, instead of 12 amps at 1,200 RPM, now you might be drawing only six amps. And your wiring size can now be reduced."

There are cost savings to be had in large facilities, too. By one estimation a typical data center relies on 500 motors in their HVAC systems. For a Microsoft or Amazon, or any entity building a data center with more than 1,000 motors, this could be a significant reduction in the capital costs of building that facility. "The upfront cost is reduced just because they use that technology," pointed out Patel. "There is operational cost reduction because we're using less energy to provide the same amount of cooling, and so there's longer-term operational savings."

The Aircore Mobility motor is covered by 32 issued patents and 44 pending patents and will be generally available in Q2 2023. *Infinitum*

Infinitum's latest generation Aircore EC motor system. *Business Wire*

Target Application: HVAC

Infinitum is rolling out its latest PCB stator motor with specific market segments in mind, said Patel during the briefing with *Machine Design*.

"We looked out into the market and we said, there's a lot of places motors are used—everything from a dishwasher motor to 40 motors in a single electric vehicle," Patel said. "Think about the car windows and the windshield wipers and the fan—there are a whole bunch of the motors there. The point being, there's a lot of applications this could potentially go into, but we decided to narrow it down to HVAC to start with, industrial second and then mobility third. And within each segment, we found a very receptive audience. Think about most HVAC systems that are running almost 24/7, and so efficiency and sustainability is key for many of these applications," he said.

Cooling and Heating Market Calls

Backing from key investors are part-and-parcel of Infinitum's success story. The start-up reported last year that it had secured $185 million in Series E funding to expand the company, increase production to meet customer demand and drive decarbonization in the industrial sector.

Industrial automation juggernaut Rockwell Automation signed an agreement with Infinitum last year, and is helping the startup break into the industrial space—specifically material handling applications. "Think again about an Amazon distribution center or UPS facility," said Patel. "They have hundreds of motors on those conveyor systems. Rockwell today supplies a lot of the VFDs that drive those conveyors with our technology, combining the VFD—the electronics, essentially—and the motors to drive those conveyor systems.

Startups like Infinitum are impacted by global economic trends. The global axial flux motor market size is projected to grow from $150.3 million in 2022 to $395.5 million by 2032, at a compound annual growth rate (CAGR) of 10.1%, according to Spherical Insights.

The global HVAC market size was estimated at $16.4 billion in 2022 and is expected to grow to $22.1 billion by 2028 and with a CAGR of 5.10% during the forecast period 2023-2028, according to a Market Data Forecast.

Patel said market size is an important rationale for Infinitum's decision to focus on commercial HVAC as a core market. Potential applications for the technology are wide-ranging, and may include process compressors, conveyors, pumps, fans, blowers, coolers, compressors, crushers, chippers and grinders.

Analysts report electric motors will see strong expansion across industries, such as automotive (which is predicted to dominate) and HVAC (systems that manage heating and cooling in industrial and commercial buildings). These industries will expand due to investments in product development. ■

Custom Motor Design: SaaS Platform Brings Flexibility to PCB Stator Design

As a SaaS offering, the Motor CAD platform enables manufacturers to advance from motor design to production in record time.

by **Rehana Begg**, Editor-in-Chief

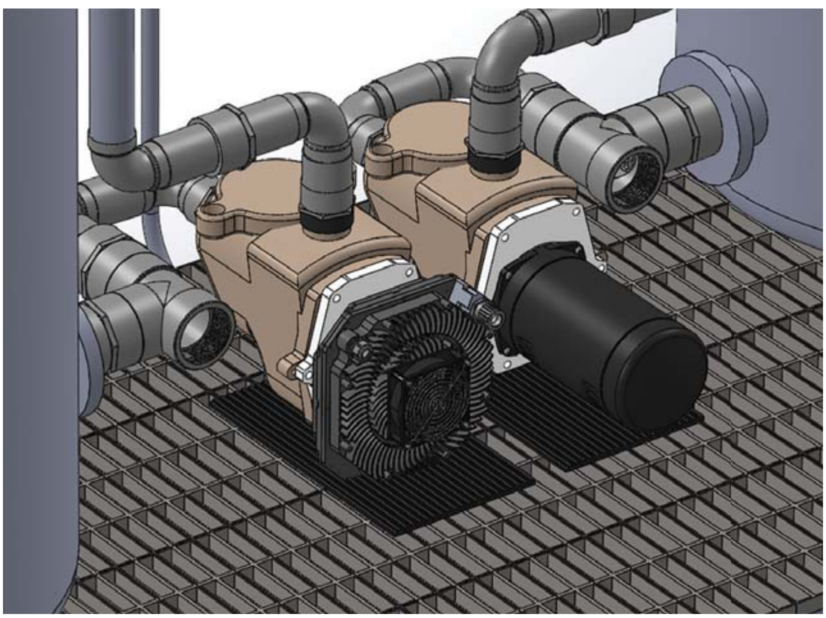
BOSTON-BASED ECM PCB Stator Tech demonstrated the company's PrintStator Motor CAD design-to-manufacture tool at CES 2024 (which took place Jan. 9-12, in Las Vegas).

The event marked the official rollout of ECM's PrintStator software design-to-manufacture tool, and demonstrated how the company is setting the pace for designing and optimizing electric motors by combining advanced motor technology and motor CAD.

The main goal is to demonstrate how design engineers, innovators and makers with varying skill levels can design custom motors, incorporating axial flux, PCB Stator technology, according to ECM's director of communications and investor relations, Jake Bright.

"At CES, we're releasing the motor kit developed by our engineering team and our chief scientist, Dr. Steven Shaw," Bright said during a call with *Machine Design*.

He characterized ECM's proprietary cloud-based interface, PrintStator SaaS, as a "motor as a software" platform, which allows the user to apply precise performance and dimensional specs to create custom electric motor solutions. The PCB design files can be printed within minutes and are ready for manufacturing.



Comparing a conventionally installed motor (right) to a PCB Stator installation (left). *ECM PCB Stator Tech*

The Demo: PrintStator Motor CAD Platform

During the call with *Machine Design*, Bright and three colleagues demonstrated how they could design a custom PCB motor within minutes. For the live demo, Lauren Donald, lead software engineer, ECM, focused on two aspects: the motor catalog and the custom design flow.

After signing in to the PrintStator motor CAD program, the design engineer can plug in constraints for the specific motor they're looking to design. Donald keyed in basic parameters for a 3hp or 2.2kW motor. The algorithm proceeded to scan for the closest match based on 8,000 designs in the database.

The platform provided the five closest matches to the specifications, including detailed parameters for high efficiency, border radius, diameter, current and voltage estimates.

Ryan Duffy, lead applications engineer, ECM, explained that the engineer can further filter the specifications and constraints to optimize for the desired custom motor design. Common constraints may include increasing or decreasing the voltage, optimal specs for the fan, the target efficiency, the radius and a custom design flow.

The user can also create a custom motor from scratch. In a custom build, the user will populate fields for speed, torque, power and size, said Duffy. Based on these and other custom parameters, the platform will default efficiency to 80% (advanced users may access advanced settings) and will prompt the user to answer queries provided by ECM's team. This exchange of information is helpful in triggering considerations the user might have overlooked, and extends the platform's flexibility, explained Duffy.

Invariably, the design engineer may have assumptions and external calculations that can be tested on the platform. During the demo, Duffy compared different magnet grades (such as Neodymium, ceramic or Samarian cobalt magnets) that are typically used in motors, analyzing the performance differences.

The user can further set the number of motor poles, the PCB layer count or PCB thickness, as well as how thick the magnets should be. In addition, the user can select bearing properties, the shaft and the rotating assembly. "Ideally, you want to keep the bounds large enough to allow the optimizer to find the best solution within that space," advised Duffy.

Once satisfied with the theoretical configuration, the user will optimize the design with thermal constraints, before generating the design and sending it to the next phase for evaluation and setting it up for manufacturing.

"I can go to the next design phase and start adding some central manufacturing constraints," said Duffy. "Depending on the complexity of the design, a design can be ready in five to 25 min., depending on how many constraints are applied and how complex the problem is."

Motor Design Tool Enables Rapid Production

ECM has to date built prototypes for a range of manufacturing industry partners, ranging from HVAC, consumer electronics, medical, robotics, renewable energy, aerospace, defense, e-mobility and fitness, according to James McMullan, who handles the company's operations in Europe.

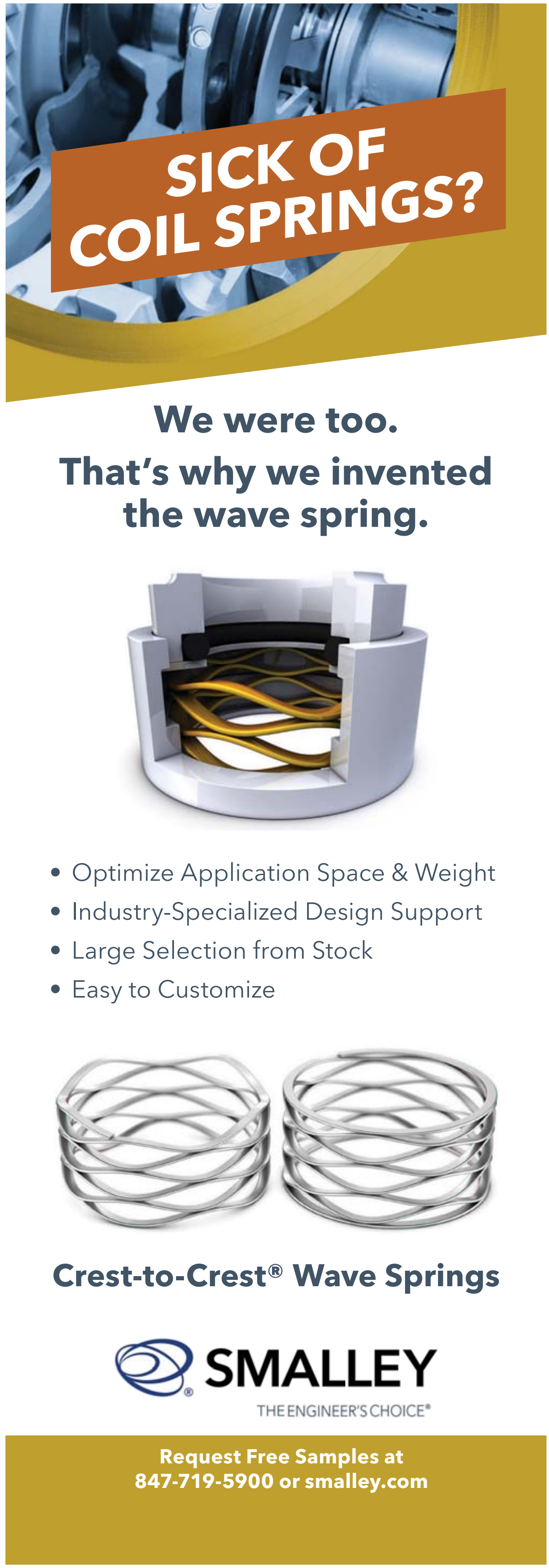
Bright said the PCB Stator innovation and PrintStator Motor CAD platform is a differentiator, as it shifts the design process away from off-the-shelf options. "Anyone, from startup entrepreneur to big company engineer, can use PrintStator for fully customized motor design."

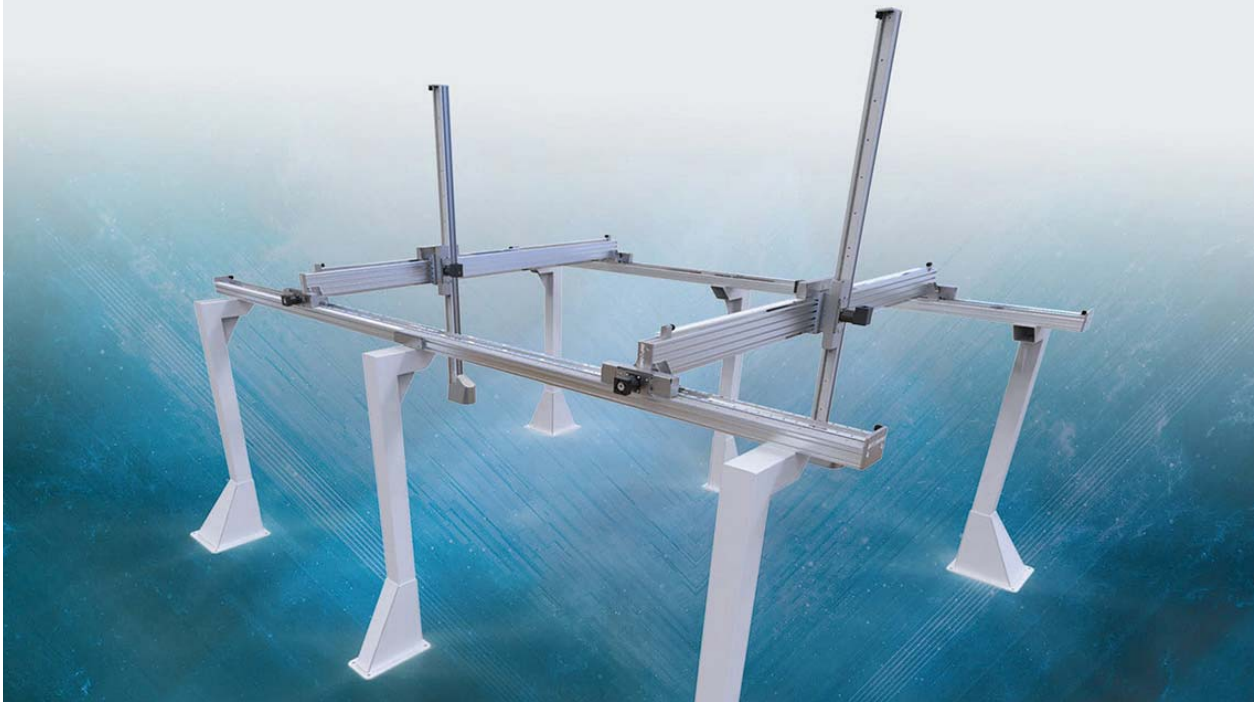
Bright counts among PCB Stator technology's advantages the fact that they are smaller, quieter and more energy and space efficient across a broad range of use cases. The PCB Stators achieve "efficiencies in the mid-90s and require just 20% of the raw materials," noted the company's website.

Machine Design reported last year on how ECM's PCB stators replace the bulky copper windings of conventional motors with a thin disc design. The PrintStator designed motors incorporating ECM PCB Stators are smaller, 70% lighter, require less materials and can reach efficiencies in excess of 90%.

ECM is a 2024 CES Innovation Awards Honoree and winner of four International SaaS Awards—including SaaS Solution of the Year; Best SaaS Product for CSR, Sustainability and ESG; and Best SaaS Product for Engineering Management, PLM or CAD.

ECM's PrintStator software is also a *Machine Design* IDEA Awards winner. ■





Moving Motors Stretch the Possibilities of Long-Travel Motion

Motion stages with moving motors can provide greater performance than traditional recirculating belt drives with static motors.

by Michael Everman, Founder and CTO, Bell-Everman

A WIDE VARIETY of industries operate factories with large-format manufacturing lines, creating a need for long-travel motion axes and transfer robots. Some of these gantry and Cartesian robots can reliably traverse distances of 50 meters or more as they transfer materials and parts around aerospace, automotive, prefabricated construction and other large-scale factories.

A common design approach with long-travel linear robots is to construct them from belt-driven linear axes, which seemingly scale well to long distances. However, not all belt drives are created equal. Traditional belt drives, in which the motor remains stationary and drives the belt via a pinion, can limit the motion system's performance due to belt sag and varying stiffness along the belt length—both problems that become more pronounced as travel lengths exceed 15 meters.

An alternative approach is to use an advanced belt-drive in which the motor is mounted to and moves with the belt drive's carriage. A ServoBelt Linear (SBL) drive operates this way and very differently from a conventional single-belt drive. This moving-motor design has a number of performance advantages, which are magnified as travel lengths increase.

This article examines some of the drawbacks associated with conventional belt drives and show how moving motor designs can improve the performance of long-travel motion control systems.

The Problem with Belt Drives

Conventional belt drive actuators or stages have an obvious problem as they scale to long lengths. Because the belt is often unsupported, it causes the belt to sag or droop in the middle while the belt remains tight at both ends, imparting an asymmetrical, variable stiffness within the belt as the payload travels. Stiffness reaches near-symmetry when the payload is at the maximum or minimum distance away from the static motor that drives the belt.

The variable stiffness of a standard belt drive is a considerable challenge when aiming to accurately convert rotational motion to linear motion. Without accurate rotational-to-linear conversions, it is difficult to achieve accurate control and positioning. Engineers attempting

The Pros and Cons of Standard Linear Motion Solutions

THERE ARE MULTIPLE DESIGN strategies to achieve linear motion, but adhering to conventional designs can limit the performance of a linear motion system.

While gear drives are commonly used, they often result in performance compromises regardless of type, size, material and other properties. Belt drives are also viable for linear motion systems, but conventional belt drives often face stiffness-related challenges.

When specifying a long-travel motion system, it is important to recognize the benefits and drawbacks of both gears and belts.

Gear Drives

Gear-driven systems often achieve accurate positioning due to their excellent driveline stiffness, but they introduce backlash or play—when gears are turning without moving the payload. Backlash prohibits direct encoder readings, which makes it a challenge to obtain precision in bi-directional repeatability.

However, backlash is often eliminated by removing any clearance between gear teeth. The lack of space between gear teeth with little to no compliance causes metal gears to generate a pronounced torque ripple effect, applying mechanical stress to other in-line components.

Nearly all modern manufactured gears are designed with involute teeth profiles as a means to eliminate backlash while delivering the smoothest possible conversion of rotary to linear motion. But no gears achieve 100% smoothness. The torque ripple effect is inherently present within gears, responsible for the noise, inefficiency and wearing of gear drives.

A traction drive is an alternative to the standard gear drive. Based on a gear type with practically "infinite teeth," it attempts to eliminate torque ripple.

Traction Drives

Also known as capstan drives, traction drives minimize torque ripple effects in order to maximize smoothness and efficiency. However, they only achieve this performance improvement at the cost of individual tooth depth and strength, as well as reduced force capacity.

Traction drives may practically eliminate the torque ripple effect, but they also bring new issues like drive roller and bearing runout (the radial error about the central axis in a rotational mechanism). Special concern is also necessary to maintain traction on the rail; enough force must be applied to induce motion, but not so much as to cause slip.

While traction drives reduce backlash and improve efficiency, they lack force damping and economical payload capacity. A possible solution to these performance challenges is to design the traction drive with softer materials such as elastomers. But when an elastomer traction drive rests for extended periods of time, flats will form on the wheel's surface that will negatively impact motion and positioning.

Rack and Pinion Drives

Rack and pinion drives are commonly used in Cartesian gantry designs, but their cost quickly balloons when manufactured or pieced together to long lengths. And because rack and pinion drives are designed with conventional gears, they are prone to backlash issues.

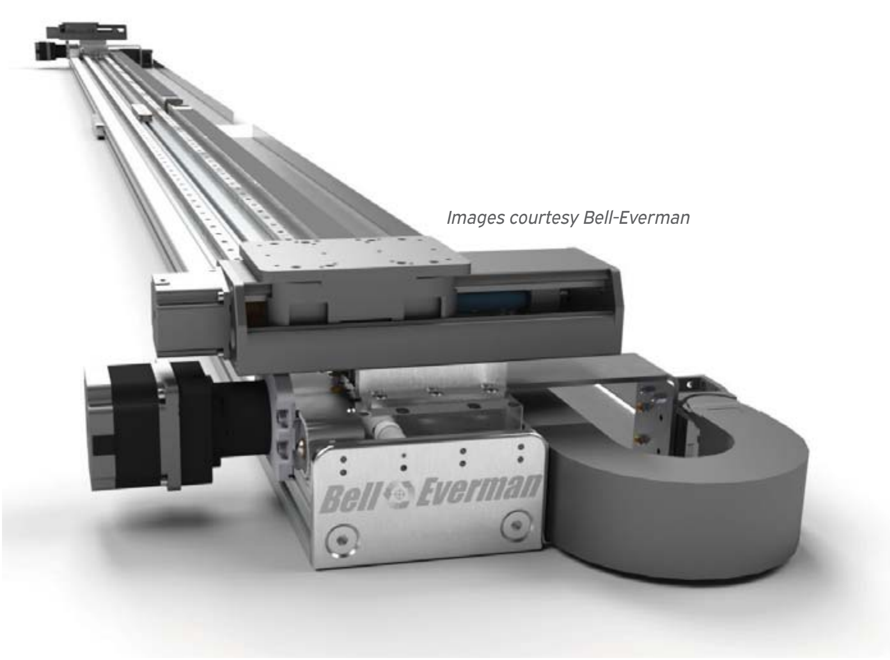
Designing the rack and pinion with spring-based anti-backlash creates an asymmetrical stiffness on either side of the payload, increasing the difficulty of achieving high-gain servo tuning.

to implement high-performance control models in their belt driven actuator will need to perform control-loop tuning in the belt's least-stiff orientation as well as additional detuning—or invoke complicated gain scheduling schemes.

These control and positioning hurdles must be overcome in order to achieve a precise and accurate linear motion system, but it is often not worth the time, money and effort to develop the necessary control models. For these reasons belt drives are generally relegated to simple material-handling tasks.

The Benefits of Moving Motors

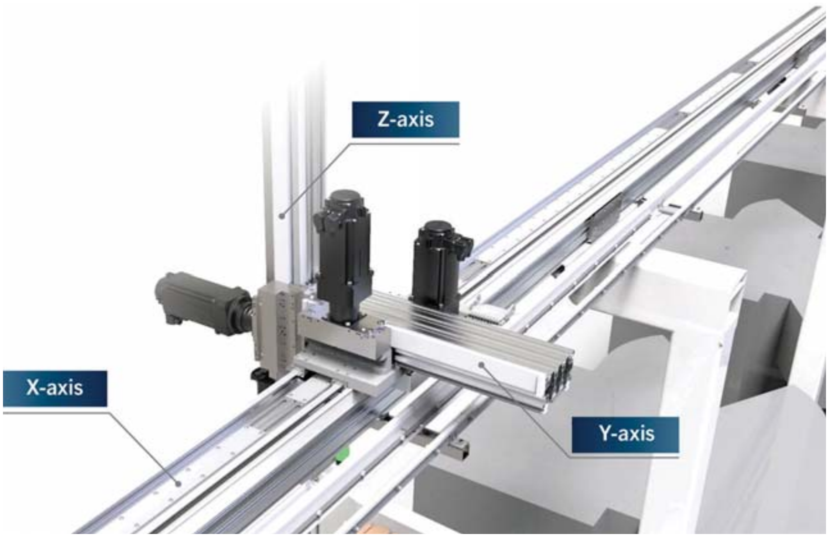
The commonly sought-after advantage of the conventional static motor approach is to limit the moving mass of the axis to only the payload. This may



Images courtesy Bell-Everman

be a cost-effective solution in short-length, light-duty applications. While using static motors to drive a linear axis is an adequate design for less-demanding applications, performance falls short when travel lengths exceed the critical length of 15 meters.

At this length and beyond, the advantage of a reduced payload weight is more perception than reality. This traditional design isn't just vulnerable to backlash, inertial forces and difficult-to-achieve precise positioning—it also incurs high costs when manufactured at long lengths.



Properly designed moving motor drives deliver essential benefits to long-length motion axes, including maintaining driveline stiffness throughout the entire travel length, despite adding weight to the payload. This design also allows for multiple carriages to travel on the same axis, as well as both vertical and horizontal application. With this design flexibility, moving motors provide major throughput advantages by enabling multiple operations to be performed on the same axis—changing the game in long-travel motion systems.

While static motors are often implemented to lighten the payload, in long-length applications, they generally feature long recirculating belts that outweigh any light-weighting advantages. At the critical length of 15 meters and longer, the driveline belt is too heavy and actually hinders performance.

By comparison, moving motors boost an actuator's efficiency by enabling designs with lighter belts, essentially removing mass from the entire drive and actuation system. It may seem counterintuitive to add weight to the payload with a shorter recirculating belt that is contained within the linear stage housing, but the efficiency gains are actually greater than initial expectations since long, heavy belts are no longer a driveline component.

A driveline needs to be as stiff as possible to achieve smooth and accurate linear motion. Many in-series elements—from the motor's magnetic fields to payload weight—define driveline stiffness. Moving-motor designs keep the belt short, light and tight. And since the active portion of the belt is contained within the motor housing and not located adjacent to the motor, it maintains a constant, symmetrical driveline stiffness as the payload moves.

Symmetrical driveline stiffness also improves a moving motor's positioning accuracy and enables linear motion system designs that feature a zero-backlash driveline. With a zero-backlash driveline, linear encoders can directly read the load position, facilitating closed servo-loop operation and other housekeeping functions such as sinusoidal motor commutation.

Keep in mind that to achieve a zero-backlash driveline without incurring torque ripple effects, it is necessary for the driveline to exhibit some degree of compliance and damping properties. Without a damped driveline, high-frequency disturbances will transmit into the rest of the structure. However, belts designed with stiff-yet-compliant materials can nearly eliminate backlash and deliver precise motion.

When Non-Standard Solutions Achieve Success

Moving motors are an effective design that outperform static motors in long-travel linear motion applications—and at a reduced cost. They provide excellent driveline stiffness, positional accuracy and energy efficiency while allowing multiple carriages to travel along the same axis. This design successfully stands up to motor inertial factors such as backlash, driveline stiffness and speed that inhibit long-travel motion axes. ■

Multi-Axis ServoBelt Linear

The ServoBelt Linear Advantage

Both short- and long-length linear motion applications can benefit from an innovative linear-actuator design, which outperforms conventional belt-drive designs. The ServoBelt Linear actuator, for example, differs from conventional single-belt drives by utilizing two mating sets of polyurethane, steel-reinforced gear teeth that perfectly mesh together. This actuator design is topologically similar to a rack and pinion, and visually similar to an "omega" belt drive.

This actuator design allows the driving belt to remain under constant tension around the pinion, minimizing belt stretch and uniforming driveline stiffness throughout the entire motion travel length. For further precision and accuracy, a ServoBelt Linear actuator's belt mesh is preloaded on either side of the pinion—ensuring zero backlash as the carriage moves in either direction. Zero backlash allows the use of linear encoders, which allows performance only matchable by linear motors.

These actuators are ideal in high-performance applications because of their precision, repeatability, cost and speed. They are ideal for applications in semiconductor manufacturing, packaging, aerospace assembly and other high-performance, high-precision industries.

R&D Spotlight: Certifiable Digital Twin Models for Power Drive Systems

UL Solutions helped Siemens navigate compliance requirements for a temperature rise test on a power drive component.

by Rehana Begg, Editor-in-Chief

Digital twin modeling allows engineers to design, commission and optimize applications for components such as Siemens SINAMICS G220 variable frequency drives. *Siemens*

THE MANUFACTURING INDUSTRY, a leader in digital twin adoption, is just beginning to grasp the value hidden behind digital twins.

This maturity was recently marked by the announcement that UL Solutions granted Siemens certification for using digital modeling and simulation to navigate compliance requirements of a power drive system. The development was not only a first for the German tech conglomerate but also represents a milestone in the field of digital twins.

Siemens approached UL Solutions back in 2018 for support with developing a digital model of the temperature rise test for a power drive component, according to Dr. Dirk Linzen, head of Test and Customer Escalation, Motion Control, Siemens AG. Siemens would leverage UL's internal simulation and testing capabilities and the collaboration would culminate in the development of a verified simulation model for conducting temperature rise tests on a digital twin of a Siemens' SINAMICS G220 variable frequency drive.

A temperature rise test is required for certification to the second edition of UL/IEC 61800-5-1, the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy. UL Solutions' modeling and simulation services offers a proprietary verification and validation process to confirm the credibility of digital models for compliance.

The research project team, led by Linzen and consisting of a global team of Siemens and UL engineers, would need to prove the level of accuracy of their simulated models. "There was a lot of initial skepticism in the beginning, but also a 'can do' mentality," said Linzen. "Now, we believe a verified and validated digital twin can deliver just as good results as a physical measurement—sometimes even better."

AT A GLANCE:

- Digital modeling and simulation have wide-ranging implications for product design and certification, including a more efficient pathway for product design and certification.
- Siemens SINAMICS G220 variable frequency drives are behind a digital twin model created for certifying a temperature rise test for a drive component.
- UL Solutions' modeling and simulation services offers a proprietary verification and validation process to confirm the credibility of digital models for compliance.
- The takeaway: Integrated digital modeling and simulation can be used alongside traditional physical tests.

What is a Digital Twin?

A digital twin is a virtual representation of a physical object. According to Siemens, its core component is a simulation model that incorporates all data and information from a physical object—in this case, the SINAMICS G220—to generate a virtual model of the behavior of the simulated object.

The physical object can be digitally connected to the digital twin throughout its lifecycle—during engineering, commissioning, operation and service—and can provide actionable insights across domains, from design and engineering to operations and maintenance.

What's Unique about Certifying a Simulation Model on a Digital Twin?

A power drive system is a complex electronic product or system that consists of more than 1,200 components, with many critical components relating to temperature behavior. "Setting up and running a physical test, regardless of whether it is for the design validation or the type testing, is time-consuming, cost-intensive and often inconsistent," said Dirk Mueller, manager, principal engineering, Energy and Industrial Automation at UL Solutions.

In the realm of electronic products, he said, components are subject to change and often lead to frequent repeats of the tests. "While running a digital model of the temperature test may be more complicated initially and requires additional physical validation testing, it pays off during the lifecycle of the product and across the entire product platform since the verified originally and validated model can be leveraged for design variances (within the agreed context of use) and design optimization during the lifecycle," explained Mueller.

How Accurate are Simulated Models in the Design Phase?

Simulation is an iterative process of physical testing and validation, and requires updating of the digital model that will provide acceptance. The objective is for the simulation model to show an equivalent level of trustworthiness to the physical test.

"UL Solutions' model verification and validation program mirrors the requirements of physical tests like ISO 17025 in the digital world," said Mueller. "Close collaboration among the different engineering disciplines, including the product domain experts, the simulation engineer and the certification/compliance manager, is critical to help ensure a product going to market meets safety requirements."

That said, using simulation without the proper parameters in the design phase is simultaneously a challenge and an opportunity. "Let's say a new design will be investigated based upon an existing and validated model of the previous generation with limited modification," explained Mueller. "It may not match the final product. However, it allows a much deeper understanding by varying the parameters. The design team can use this model to optimize design decisions."

Compare this method to the use of prototypes. As Mueller pointed out, prototypes typically don't completely match the final product but allow engineers to investigate certain design aspects and conduct physical tests. "The test results don't replace the final certification test on a final product," Mueller said. "It is the same here in the simulation world. After the design freeze, the necessary information is typically available and can be fed into the model to get suitable results."

Known Criteria Help Validate Simulation Outcomes

In the case of variable frequency drives, in particular, engineers would have access to known criteria that are relevant for certification. Among those parameters are the component's CID data; knowledge about losses in the component; and an understanding of air flow in the design of the drive itself, as well as with fluid dynamic simulation models.

If one understands how the component performs against the highest temperatures, said Linzen, one can identify whether an application is feasible, whether it can operate within the safety margins and also how the component's reliability is affected. "We are now able to really detect and simulate the temperature distribution in the drive itself," said Linzen.

What Does the Certification of a Digital Component Mean for the Future?

Mueller estimated the amount of physical testing can be reduced significantly with certification protocols in place. There will always be a physical test to validate the digital model and to verify the ability to manufacture what has been designed, he said. For manufacturing companies, the endgame would invariably be to develop solutions that lead to lower costs and lower energy usage throughout the product development process.

This is made possible when fewer prototypes and laboratory testing are needed, maintained Mueller. Design failures and failed tests at the end of the development process are a significant cost driver. Applying simulations and using digital twins early in the project significantly reduces risk.

"Product updates, when changing components or optimizing the design otherwise, will be accelerated due to reliance on the originally verified and validated model, which eliminates further physical testing within the agreed context of use of the model," explained Mueller.

Shift Left Approach

For Linzen, the ability to reduce the number of prototypes is an added value, as it reduces cost and saves valuable time.

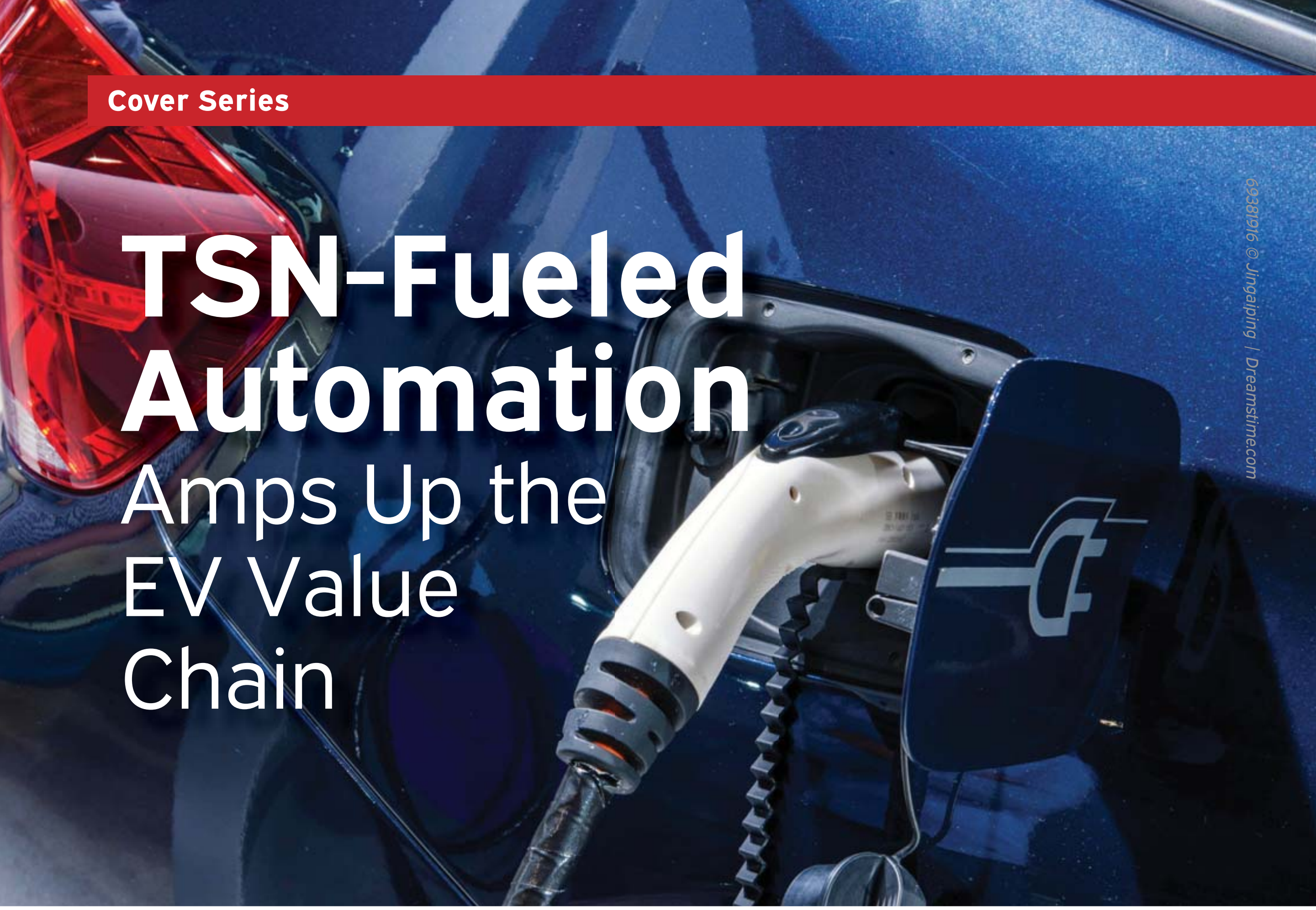
Additionally, he said, the development of the simulation model has solidified his team's "shift left approach." Having early validation of a design means that it's possible to think of alternative, better design options, cost optimize, anticipate changes and build fewer prototypes.

"Of course, customers can then benefit foremost," he said. "We, as manufacturers, benefit because we reduce the risk in the project, but we also reduce time to market." ■

Cover Series

TSN-Fueled Automation

Amps Up the EV Value Chain



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AT A GLANCE:

- An unprecedented surge in electric vehicles (EVs) is reshaping the automotive landscape, with industry players in the U.S. aiming to charge ahead in the race to offer competitive, cleaner and greener transportation options.
- The authors argue that, if manufacturers are to succeed, they should invest in cutting-edge factory automation equipment and open network technologies that can support the needs of this changing market and new production requirements.

by Anthony Pawlak, Director, Global Key Accounts (Automotive), Mitsubishi Electric

Tom Burke, Global Strategic Advisor, CC-Link Partner Association (CLPA) Americas

A look at how future-oriented industrial automation and time-sensitive network technologies can help drive the successful electrification of the automotive industry.

RECENTLY, OEMS WORLDWIDE have been intensifying efforts to implement major EV developments and support global decarbonization efforts. Global electric car production nearly doubled between 2021 and 2022, reaching a record-breaking output of 10.3 million units for 2022. Data for 2023 show potential for further growth, with a total of 6 million new battery and plug-in hybrid EVs delivered during the first half of 2023.

With more than 660,000 new EVs produced in 2022 and an estimate of more than a million new units in 2023, the U.S. represents a region where momentum is unmistakably gathering. Electric car sales in the country, which is the third largest market on a global scale, increased by 55% in 2022. When looking at battery manufacturing capacity, calculations indicate that local plants have been able to produce sufficient batteries to supply more than 1 million passenger vehicles between 2022 and 2023.

As the amount of investment and scale of production capacity in the U.S. are likely to continue growing, there is great potential for companies in the EV value chain to enhance their market share and establish their products as industry standards. These opportunities are supported by the sector's well-established propensity for innovation, with highly automated shop floors attesting to it. With production facilities shifting from traditional internal combustion engine (ICE) to lithium-ion battery (LiB) manufacturing processes, industrial automation solutions and their latest advances can help address current and future challenges.

Changing Operational Requirements

Perhaps the greatest difference between ICE and LiB operations is the processing speed, which raises the bar on the requirements for motion control applications. More specifically, machines and their components need to be able to communicate with short cycle times and have high positioning accuracy. Any imprecision can potentially impact the end performance, capacity and safety of LiBs.

The need for fast operations is also amplified by the booming demand for EVs, with battery demand for vehicles in the U.S. growing by around 80% in 2022. To feed this demand, companies need to optimize their manufacturing activities, which includes shortening their lead times and maximizing the throughput of quality products.

In addition to responsive communications, EV and LiB production facilities need to be able to reliably handle extremely high volumes of data. These are also continuing to increase as plants and enterprises become increasingly more digitalized. For example, to support effective, data-driven decision-making, it is important to deliver shop-floor data to higher enterprise-level systems and process them through advanced analytics and mining models to generate actionable insights.

To address all these challenges, companies across the EV value chain need to quickly invest in advanced industrial automation systems that leverage best-in-class devices and high-speed, deterministic network technologies. Favoring solutions equipped with Time-Sensitive Networking (TSN) functions is a good starting point to meet these requirements and establish successful operations.

TSN Can Fuel the Creation of Smart EV and LiB Factories

In effect, TSN was developed by the IEEE 802.1 working group to complement standard Ethernet and offer enhanced capabilities, including deterministic performance. One of the key features of TSN is specified by the IEEE 802.1AS standard, which focuses on establishing accurate, distributed time synchronization across numerous axes. When applied to motion control applications, users can benefit from timely and dependable transmission of timestamped data, enabling faster-than-ever cycle times. This means that all TSN-compatible interconnected devices can be coordinated with greater precision than with other solutions, which can deliver higher performance and greater accuracy, as well as enable capabilities previously not possible.

Moreover, TSN can prioritize time-sensitive traffic, as defined by the IEEE 802.1Qbv standard. It can also allocate cycle time for the exchange of regular messages, such as control data packets. What's even more significant is that these functionalities remain intact even when dealing with substantial volumes of less-transient traffic types transmitted over the same network.

This ability to allocate specific timeframes for recurring, time-critical signals goes beyond determinism, as it opens the door to convergence. Hence, the technology is viewed as a gateway to support future-oriented Industrial Internet of Things (IIoT) and smart manufacturing applications.

Acting Now

U.S. manufacturers looking at future-proofing their production lines with TSN should consider a number of aspects. Firstly, as the region grows its share of the global market, companies need to strengthen their relationships with suppliers worldwide, especially in key areas such as Asia. Also, they should think of their plants not as individual entities, but as nodes of a greater network.

Therefore, selecting open network technologies that are widely supported by industrial automation vendors worldwide is highly beneficial. This holds even truer when the communications solutions are also widely used among key suppliers and the regions where they are based.

CC-Link IE TSN network technology and its range of compatible industrial automation products are ideal to meet these requirements. In effect, CC-Link IE TSN is the first open industrial gigabit Ethernet with TSN functions, and already has a portfolio of hundreds of conforming devices. As the network technology—which is a de facto standard in Asia—is open, the available solutions come from a variety of global vendors, including Mitsubishi Electric.

Key Opportunities for Manufacturers

Well over 100 industrial automation components such as state-of-the-art controllers, drives and accessory devices are compatible with CC-Link IE TSN. Especially appealing to EV and LiB producers are servo motors equipped with cutting-edge servo amplifiers and encoders that can deliver enhanced performance across multi-axis servo systems. Through CC-Link IE TSN compatibility, these drives can be connected with a multitude of devices from multiple vendors.

Even more, within the range of CC-Link IE TSN certified servos, key solutions make it possible to synchronize up to 256 axes and users can benefit from communication cycle times of 31.25µs, enabling applications to reach a maximum motor speed of 6,700 r/min and even up to 10,000 r/min.

When it comes to additional analytics for business intelligence, a variety of CC-Link IE TSN compatible servos support predictive maintenance functions through artificial intelligence (AI). Therefore, users can detect mechanical component deterioration on the machine long before any maintenance requirements arise, optimizing scheduling and maximizing uptime.

As U.S. companies across the EV value chain ramp up their productivity and capabilities, the role of automated machines becomes increasingly pivotal. In this transformative journey, those who embrace the latest technologies can enhance their competitiveness, delivering valuable products and propelling the entire sector though its era of electrification. ■

Key Component Integration for High-Performance Robotic Joints

Cross-examine the design and specs of the separate components that make up maxon's robotic joint solution.

by Biren Patel, Head of Business Development, maxon precision motors, inc.

The high performance robotic joint modules shown here are designed specifically for small-scale operations requiring a low profile, lightweight system that offers zero-backlash and precision positioning to the industry. *Images courtesy maxon*

ROBOTICS HAVE INFILTRATED most industries, including packaging, assembly, machining, medical and many more commercial and industrial applications. The majority of these applications are for small, lightweight systems such as industrial in-line robots, surgical robots and cobots. When designing for such applications, design engineers are tasked to focus on compactness without losing the precision and load-bearing capabilities needed for specific tasks.

These challenges have led manufacturers to consider ways to integrate multiple components into a single installed unit such as robotic joints. Such packaged solutions have allowed for very small footprints, particularly when compared to the alternative that includes a separate motor, gearbox and encoders that must be purchased and mounted together.

To provide the best possible product for robotic joint systems, maxon has designed and manufactured their high-performance joint (HPJ) line of robotic joint modules. These integrated devices consist of an EC frameless DT motor, a strain wave gear, a motor encoder, an output absolute encoder, an optional braking device and a high-accuracy position controller board.

EC Frameless Motor

Frameless motor components are designed for high-torque applications. Each includes an electromagnetic stator and permanent magnet rotor that operate like a conventional, synchronous motor. These motors are used to drive a high-ratio gear set and possess higher pole counts that are able to increase torque output. Large through-holes allow for optimized packaging, and allow the user to incorporate cameras, sensors or cabling for other devices.

The EC frameless motors offer a very low profile, which makes them ideal for robotic joint applications. The HPJ line of high-performance robotic joints offer nominal output speeds from 10 rpm to 35 rpm to handle a wide range of operations. Maximum possible output speeds based on the use of a 48 VDC supply are in the range of 15 to 65 rpm. The use of a frameless motor in the HPJ line eliminates cogging during slow speeds, which delivers fine, smooth and predictable motion inside the robotic joint system.

maxon's EC line of brushless motors delivers the performance and long-life capabilities required in the robotics industry. Frameless motors not only offer increased performance in a compact package, but offer more flexibility in shaft and bearing selection when compared to a traditional motor.

Strain Wave Gears

Position and movement play hand-in-hand in a robotic joint application. Robotic joints encompass varying reflective loads and inertia depending on position, which continues to change throughout an operation. Gear reduction permits the use of smaller motors that further require less power and provide higher efficiencies. To provide these benefits while maintaining zero backlash in the system, maxon incorporates strain wave gearing as part of the HPJ module.

Strain wave gears consist of only three main parts: a circular spline, a flexible spline and a wave generator. The wave generator rests inside the flex spline, which forces the flex spline into an elliptical shape that causes the teeth of the flex spline to engage with the teeth of the circular spline at two opposing regions across the major axis of the ellipse. Because the gear teeth are always fully engaged, these gearheads produce zero backlash as well as the high torque capacity that robotic joints require. The strain wave gearbox is compact and lightweight and provides superior position accuracy and repeatability.

Robots used in a variety of applications may require a braking system to provide holding torque once an operation is halted. Braking systems are essential when an operation requires that the robot joint holds position when power is lost or a signal is interrupted.

Dual Encoder Design

The maxon high-performance joint modules are equipped with two positioning encoders, one mounted on the input for commutation and one on the output for positioning. Encoder feedback for the motor drive enables the system to offer smooth velocity trajectories to the user while providing the ultimate in motor efficiency. The maxon TSX 50 MAG is an incremental encoder with two channels and provides 2,560 counts per turn.

For the output encoder, the HPJ Modules incorporate a TSX RIO absolute encoder with 21-bit resolution. As one of the more critical components of the robotic joint modules, the output encoder is responsible for the precision of the joint itself. In a variety of applications, it is critical that the robot controller rely on the output encoder as a way to compensate for various levels of deflection that can occur as a combination of all the joints as they work together.

The absolute encoder maintains precise location of the joint even during the loss of power—homing is not necessary. Other challenges in precision could be environmental, including temperature or humidity variations that could affect each joint's movement differently. The absolute encoder provides the necessary feedback to the controller to mitigate these variations as well.

Braking Option

Robots used in a variety of applications may require a braking system to provide holding torque once an operation is halted. Braking systems are essential when an operation requires that the robot joint holds position when power is lost or a signal is interrupted.

Robotics designers are finding it easier and more cost-effective to simply implement a single subassembly as a solution.

This can be during an emergency situation where a person has stepped into the line of movement for the robot, if a tool gets in the way of an operation, or while the robot is performing a series of stop and go movements such as in a material handling, inspection or surgical operation. In keeping with other components used inside maxon's HPJ modules, the electromagnetic brake is compact and lightweight.

Position Controller

Usability is key when incorporating a robotic joint solution. On board electronics for maxon's HPJ57 modules are delivered through a ready-to-connect high-performance EPOS4 positioning controller. Integrating the motor control electronics inside the HPJ module delivers significant benefits, including speed and torque control for precision positioning, command of brake engagement and disengagement when needed, EMI and RFI shielding, and communications through EtherCAT and CANopen. Integrated control electronics means reduced wiring costs as well.

These controllers are designed using cutting-edge technology and manufacturing techniques. The EPOS4 controller board is suitable for efficient and dynamic control of brushed DC motors as well as the BLDC (EC) motors used in the robotic joint modules. EPOS4 is a modular, digital positioning controller that provides superior control performance, extremely high-power density and up to 98% efficiency. The board is equipped with temperature monitoring capabilities and is shock- and vibration-resistant.

Conclusion

High-performance robotic joint modules, such as maxon's HPJ57, are compact, low-profile robotic joints configured for lightweight applications. Offering the highest power density and most efficient operation in a single unit, the HPJ modules are ideal for cobots, surgical robots and small in-line manufacturing applications. All individual components for each HPJ product are fitted to work together seamlessly and with the utmost precision. ■

Insights from MD&M West: Keynotes, Sessions and Exhibits

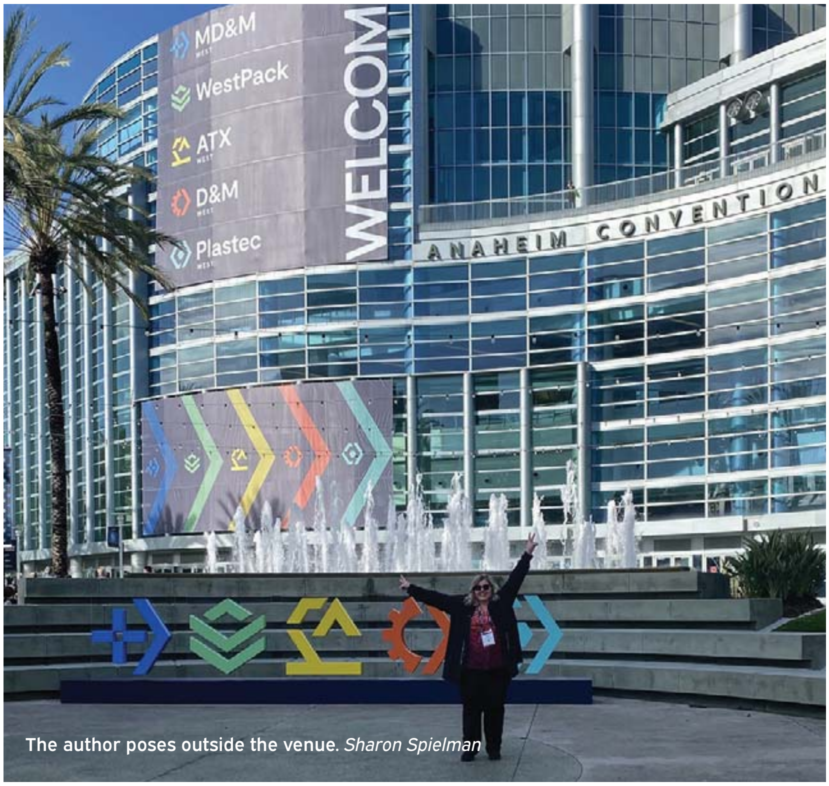
The medical design and manufacturing event addressed the needs of the growing medical device industry through presentations and exhibits that did not disappoint.

by Sharon Spielman, Technical Editor

MD&M WEST, THE ANNUAL B2B medical device show that brings together a host of MedTech companies, was co-located with four other show brands—ATX West (automation), WestPack (packaging), D&M West (design) and Plastec West (plastics manufacturing)—under the umbrella of IME West 2024 and took place Feb. 6-8, in Anaheim, Calif.

The medical devices industry has grown strongly in recent years and is forecast to continue this growth, climbing more than 5% a year to reach nearly $800 billion by 2030, according to KPMG. These figures are indicative of demand for innovation in new devices and services such as wearables and data-driven offerings.

The medical design and manufacturing event addressed this growing demand for innovation via a host of sessions and exhibits for medical device engineers, including keynotes that did not disappoint.



The author poses outside the venue. *Sharon Spielman*

Flex's Samproni on Integration for Patient Outcome

In her keynote address Transforming the Future of Patient Care with Human Machine Interfaces, Jennifer Samproni, CTO and head of global R&D at Flex, shared her perspective about how HMI can impact patient outcome.

Speaking directly to the makers and builders in the audience, Samproni said, "We're not just designing the devices; we are creating the experiences that will improve patient outcome and improve patient care."

She says our responsibility with HMI is to leverage technology and blend it seamlessly with the human experience

Flex's Jennifer Samproni. *Sharon Spielman* and the human touch. Augmented and virtual reality will play a role in this. "As we move to AR and VR and HMI into the medical segment, we're able to simulate and craft user experiences in real time," she said. "In fact, we're seeing a revolution in medical education, telemedicine, and remote patient monitoring and diagnostics."

Samproni addressed the four megatrends that she sees as disruptive forces in this space.

- The first is an aging population—one that is older now than it has ever been. The median age went from 30 years old to 39 years old between 1980 and 2022, she noted, and one in six people have a chronic disease, including stroke, cancer, diabetes and heart disease. She says we expect a 47% increase in the number of people who are 65 years old and older between now and 2050 in the U.S.
- The shifting sites of care is another disrupting factor. With hospitals being overburdened and overrun, it is becoming more challenging to find skilled labor. "Add to that, that according to the CDC, one in 31 patients on any given day will have a hospital-acquired infection," she said. This is why it makes sense to move care outside of the hospital to points of patient need except for the more critically ill patients.
- Another megatrend is the escalating costs of care. "Chronic disease is not only the No. 1 cause of death and disability in the United States; it is also the leading driver of healthcare expenses," Samproni said, adding that overlaying all of this "and really pouring gasoline on the fire was the pandemic."
- She said the fourth disruptive trend is digitalization. "We are in an increasingly connected world," she said. "As we think about the devices that we have, we need to be able to integrate them seamlessly into our practicum of care. Just like we've seen on the consumer side, it is drifting and evolving into the medical device arena in order to create more actionable, meaningful insights that come from the vast amounts of data that our devices are delivering."

We think of HMI historically as buttons, switches and screens to operate a piece of equipment or a device, and this takes knowledge and experience, she said. As we think about the challenges with skilled labor and moving from skilled practitioners into a user's home, "You can really see why the onus is on making interactions with machines more intuitive, more natural, more seamless," Samproni noted, adding that this is why we are starting to see more gesture-based systems, more systems that are a natural extension of our normal behavior—even voice-activated systems. It is all about integration.

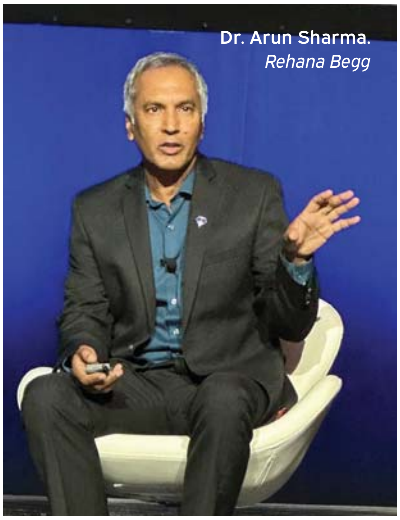
"Everything that we are thinking about now have to be patient- and practitioner-focused, whether it's a diagnostic instrument or a wearable device," she added.

The Gravity of Gravity

The keynote Manufacturing Beyond Gravity: Unlocking the Potential of Space for Innovation on Earth on the Axiom Station discussed the potential for manufacturing in space. Are we shooting for the stars, or could space be the place for innovation and for solving Earth's industry challenges?

The world's first commercial space station, Axiom Station, has access to microgravity that could enable commercial-scale manufacturing of materials with fewer defects, more uniformity and improved quality.

During the discussion, Dr. Arun Sharma, assistant professor, Board of Governors at Los Angeles Cedars-Sinai Medical Center, said that everything is different when you remove that variable of gravity from the equation in terms of how our bodies and cells respond to that environment, and for the purpose of manufacturing, "that can be a huge benefit," he said.



Dr. Arun Sharma. *Rehana Begg*

A Slew of Sessions

Although it was not possible to cover all the sessions offered at the event, *Machine Design* was able to attend several. Early presentations focused on innovations in resins, surface modifications and processing. This included biodegradable TPUs for tissue repair; microbial susceptibility of various polymers and evaluation of thermoplastic elastomers with antimicrobial additives; and novel bioresorbable polymer composites for medical device applications.

Despite speakers' inability to divulge much about their "secret sauces," in one of DSM's presentations, they talked about how their proprietary filler silicate ceramic will add osteostimulative and antimicrobial properties to a greater array of strategic partners' medical devices—provided as a material, manufactured component or licensed medical device—depending on commercial and technical needs, including 3D printing ink.

The segment on the benefits of silicone and the use of surface modifications included presentations on the effects of low-energy electron beam radiation on medical device polymers; extending the capabilities of liquid silicone rubber overmolded polycarbonate; advancements in low-temperature curing liquid silicone rubber; and strategies for surface modification and adhesion enhancement for medical-grade plastics.

Maureen Reitman, consultant and leader in Polymer Technology and Product Development, presented how evolving chemical and environmental regulations on fluoropolymers impact their use in healthcare. *Sharon Spielman*

Weidmuller USA expands its PCB product portfolio with its Omnimate 4.0 PCB terminal blocks. *Sharon Spielman*

Maureen Reitman's keynote covered the global impact of PFAS on medical polymers and devices, as well as progress updates in sustainability of medical polymers. In her keynote, the consultant and leader in Polymer Technology and Product Development at Exponent presented on how evolving chemical and environmental regulations on fluoropolymers impact their use in healthcare. The takeaway: We need to find something that works like fluorine but isn't fluorine.

Speakers from Celanese Corp. and Avient Corp. followed up with presentations on the global impact of PFAS regulatory restrictions on medical plastics and navigating PFAS replacements in the plastics industry.

There were progress updates in sustainability of medical polymers, which included a presentation by Jennifer Austin from ExxonMobil Prod. Solutions, who talked about advanced recycling and the benefits that it can have. The takeaway here: Manufacturers need to design for recyclability.

Other presentations included the impact of sustainability and sterilization trends on material selection for medical devices; driving towards net zero—a sustainable and circular design approach with homopolymer polyoxymethylene; the challenges and opportunities for recycling of medical plastics; and a host of other relevant topics.

Innovative Exhibits

Nearly 15,000 attendees and 1,600 exhibitors converged on the show floor, where emerging and proven technologies alike were showcased alongside a range of inventive and forward-looking industrial products.

Here is a small sampling of what was on display.

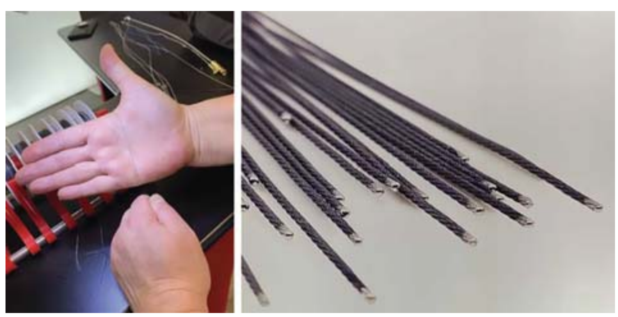
Terminal Block for Automation, Connectivity Needs

If smart industrial automation and connectivity products and solutions are your jam, then the Omnimate 4.0 PCB terminal blocks in the MTS 5 product series from could be for you. The company expanded its PCB product portfolio with its introduction at this year's show. Using its Snap-In technology, these blocks are designed for efficient wiring and signal transmission in many industrial sectors. With the new technology, conductors can be connected quickly without the need for tools and wire-end ferrules, making them suitable for the full spectrum of automated processes.

Tiny Tungsten Cables for End Effectors in Robotic-Assisted Surgery

When a surgeon's hands guide the tentacles used in robotic surgery, small tungsten cables like these from Carl Stahl Sava Industries are what ensure that the pitch and yaw required in the end effectors make the cutting, grabbing, holding, pulling, slicing, etc., possible. Because they are tungsten, when they are installed, they have about 30% to 40% more cycle count and more lifespan than stainless steel, Scott Dailey told *Machine Design* at their booth.

"This is relevant in the surgical robotic assistant surgery market as the material of choice for the end effectors of these

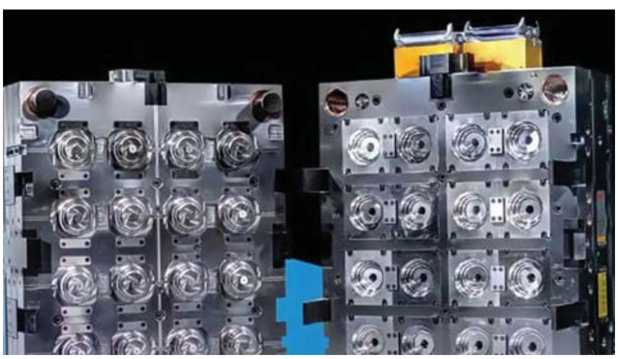


Hundreds of tungsten filaments are stranded together to create the tiny cables that are critical for making the end effectors in robot-assisted surgery work. *Sharon Spielman* machines—not the elbow or the arm—but the end effectors," he said. Hundreds of thin wires that are smaller than a third of the thickness of human hair are stranded together to create the cables.

> *"This is relevant in the surgical robotic assistant surgery market as the material of choice for the end effectors of these machines—not the elbow or the arm—but the end effectors."*

Technology-Driven Manufacturing Solutions

If you are looking for a tooling solution to meet your development needs, SyBridge Technologies Inc. showcased its ability to support every stage of the medical device lifecycle, from concept to product launch. Dr. Charlie Wood, vice president of innovation, research and development at SyBridge, said: "Since our inception, we have made significant advancements in precision and consistency. SyBridge is committed to pushing the boundaries of what is possible, ensuring exceptional precision and consistency across industries like medical devices and pharmaceuticals, from drug delivery components (syringes, inhalers) to diagnostic tools (pipettes, glucose meters) and vital cardiovascular devices (catheters, closure devices)." The company is the combination of 15 acquisitions of industry leaders made to combine different products, services and technologies into a singular technology-enabled solution.



SyBridge offers solutions from initial design to prototyping, precise tooling and validation. *SyBridge*

DMLS 3D Printed Medical Components

Among the parts that Protolabs had on display were some of its direct metal laser sintering (DMLS) projects. Chloe Vallaro showed *Machine Design* a titanium gyroid shape that is good for lightweighting, as it is not comprised of much material but remains strong. She said it is currently being explored for implants and applications such as tissue growth. The company offers a turnkey solution for producing DMLS projects, including several secondary operations for improved part quality, process validation, material traceability and quality inspections. Most of these small parts are either stainless steel or titanium and suitable for a range of medical applications.

The titanium gyroid shape is good for lightweighting as it is not a lot of material, but strong, and being explored for implants and applications such as tissue growth. *Sharon Spielman*

AMS and System Cooling for Molds

Progressive Components offers solutions for tooling performance, with product lines consisting of standard and proprietary mold components, mold monitoring devices and software, and innovations for improving mold maintenance. Its ProFile asset management system is an industry- and equipment-agnostic way to track data and assets globally. Users can create checklists and assign them to assets to view how many cycles or the date assets require maintenance.

To schedule maintenance or other activities, work orders can be utilized to track unscheduled maintenance and repairs for assets. The company's System Cooling intelligent flow monitoring for molds includes a suite of products that allows injection molders and mold makers to collect and view data on the cooling lines within a mold and the cooling parameters during production. Molders can use the system to view and collect data related to coolant flow, temperature and pressure with information recorded and time stamped for historical tracking. ■

Sharon Spielman

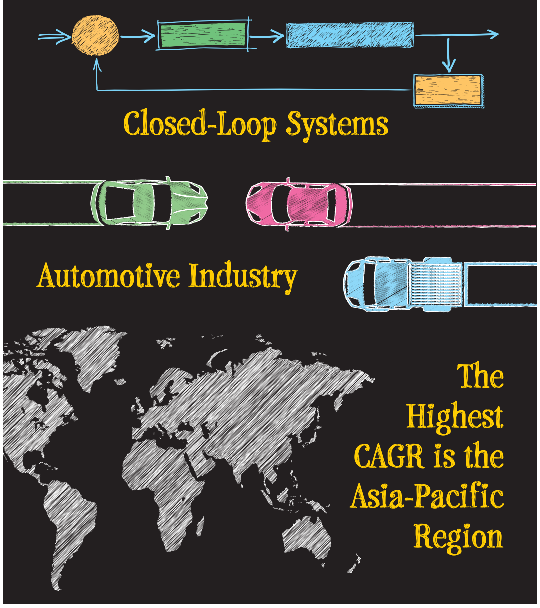
Data File / Classifieds

Ad Index

Motion Control Market Projected to Reach $21.6B by 2029

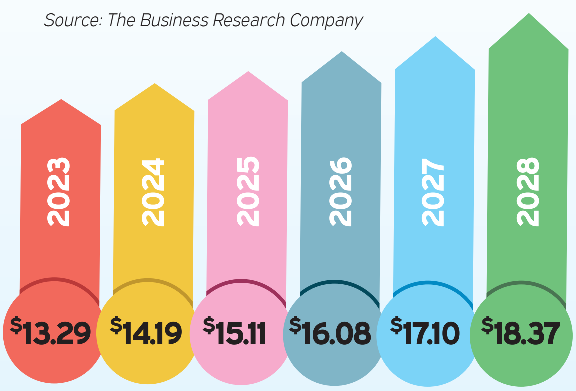
THE GLOBAL MOTION CONTROL market by offering (actuators and mechanical systems, drives, motors, motion controllers, sensors and feedback services, software and services), system (open-loop, closed-loop), end-user industry and region is estimated to be worth $16.5 billion in 2024 and forecast to grow at a CAGR of 5.5% to $21.6 billion by 2029, according to a motion control market report from Markets and Markets.

During the forecast period, the largest growth shares include:

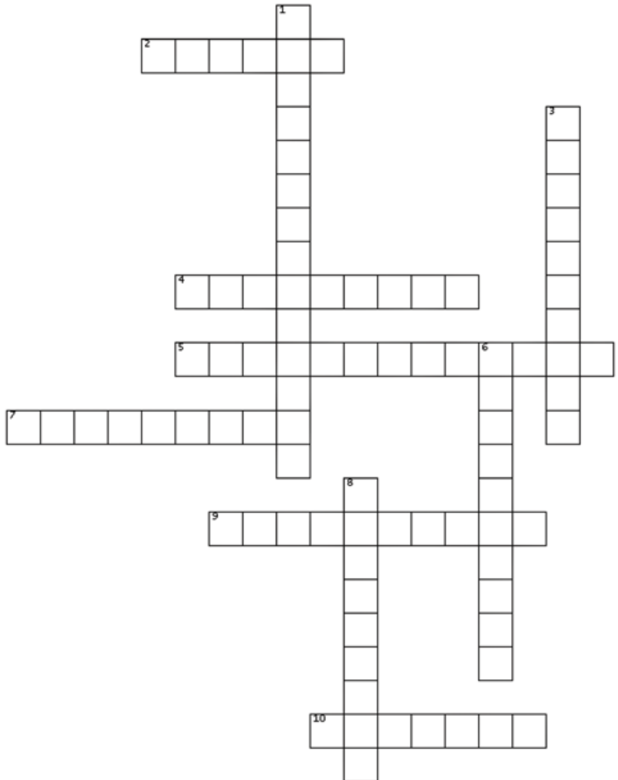


MEDICAL COMPONENT MANUFACTURING MARKET FORECAST

Source: The Business Research Company



VALUE (in Billions)



ACROSS

2. Forms a collar around an object to be held for machining

4. Identifies a need, develops requirements, generates a concept, develops a prototype, is manufactured and verified via testing

5. Subfield of automation that uses electronic energy and motors to control part movement (2 words)

7. A simple visualization of a product to test the concept

9. The E in PERT

10. This Charles was the inventor of the first mechanical computer

DOWN

1. Focus of the MD&M trade show (2 words)

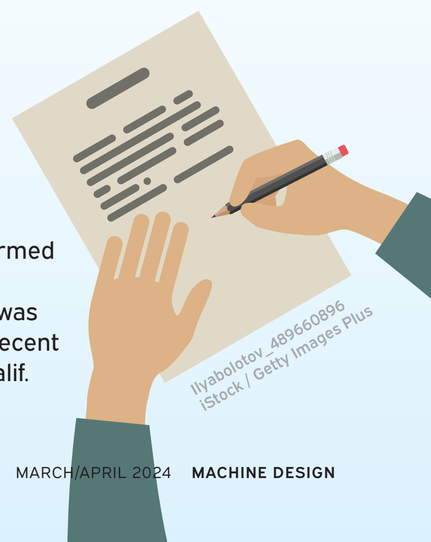
3. These hyphenated two-word systems are forecasted to have the largest share of growth in the motion control market through 2029

6. This type of milling moves the tool in a spinning motion to distribute wear across the cutting edge, extending tool life

8. The N in CNC

DID YOU KNOW?

Eagle Medical, Pacific BioLabs, WESTPAK, Steri-Tek and Blue Line Sterilization Services formed the West Coast Device Alliance (WCDA), which was commemorated at the recent IME West in Anaheim. Calif.



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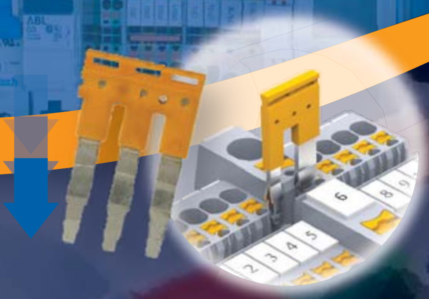

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