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Autonomy Provides New Off-Highway Opportunities

p. 10


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eBook: Motion Control Advancements for Mobile Equipment
This eBook details the technologies and trends which are shaping the future of fluid power and electric motion control in mobile machinery.
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POWER&MOTION

Volume 77, Issue 4

Power & Motion Technology (USPS Permit 254-960), (ISSN 2831-4883 print, ISSN 2831-4891 online) is published 6 times per year (January/February, March/April, May/June, July/August, September/October, November/December) by Endeavor Business Media, LLC. 201 N. Main St. 5th Floor, Fort Atkinson, WI 53538. Periodicals postage paid at Fort Atkinson, WI, and additional mailing offices. POSTMASTER: Send address changes to Power & Motion Technology, PO Box 3257, Northbrook, IL 60065-3257. SUBSCRIPTIONS: Publisher reserves the right to reject non-qualified subscriptions. Subscription prices: U.S. ($86.25 per year); Canada/Mexico ($98.75 per year); All other countries ($123.75 per year). All subscriptions are payable in U.S. funds. Send subscription inquiries to Power & Motion Technology, PO Box 3257, Northbrook, IL 60065-3257. Customer service can be reached toll-free at 877-382-9187 or at powermotiontech@omeda.com for magazine subscription assistance or questions.

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[Editor's Note]

SARA JENSEN
Executive Editor

What Role is Automation Playing in Fluid Power Systems?

The development of automation systems is bringing new technologies and performance capabilities to fluid power systems.

VARIOUS FORMS OF automation are entering the industries served by fluid power, bringing with it new technologies and capabilities, as well as new design challenges. But how exactly will hydraulics and pneumatics be impacted by automation?

A greater integration of electronics, particularly sensors, is a key change taking place. While not a new phenomenon, technology improvements and increased interest in efficiency and accuracy — both of which can benefit automation — have helped to grow the pairing of electronics with fluid power components and systems. And with the rising use of electronics has come the ability to increase the connectivity and communication between systems, which is again beneficial for the implementation of automation.

Because hydraulic and pneumatic components are becoming more electronic and software controlled, autonomy can be added explained Peter Bleday, vice president of connectors and formerly head of Autonomy at Danfoss Power Solutions, in an interview with *Power & Motion*. That digital control is a key interface between the automation system and the parts of the machine which do the work — which are typically powered by hydraulics and pneumatics.

On pg. 10, Bleday outlines the various levels of autonomy in off-highway machines and how fluid power systems may be impacted.

As with electrification, there is a question whether or not hydraulic and pneumatic components will be replaced by electric alternatives to meet the requirements of automation systems. The simple answer is that yes, in some instances electric options will be used instead because of the efficiency and precision they can provide, which are desired for automation systems.

However, this does not mean hydraulics and pneumatics will be completely replaced. There are still many applications in which they will be used, such as mobile machinery like construction equipment.

There will also be instances in which a hybrid approach pairing fluid power and electric motion control devices is beneficial as Linda Schwartzen explains in her article on pg. 16. She notes that electropneumatic hybrid automation systems, for instance, can benefit those applications in which there may be space limitations or robust operation is required and thus a combination of electric and pneumatic is the best fit.

The needs and capabilities of automation, and its impacts on fluid power systems, will continue to evolve as the technology develops further to improve safety and efficiency, as well as overcome labor challenges in various industries. While design challenges will certainly exist, there are many opportunities automation will bring to hydraulics and pneumatics including performance enhancements and new application possibilities. P&M

How are you seeing the implementation of automation impacting hydraulics and pneumatics? Let us know by emailing editor@pmtmag.com.

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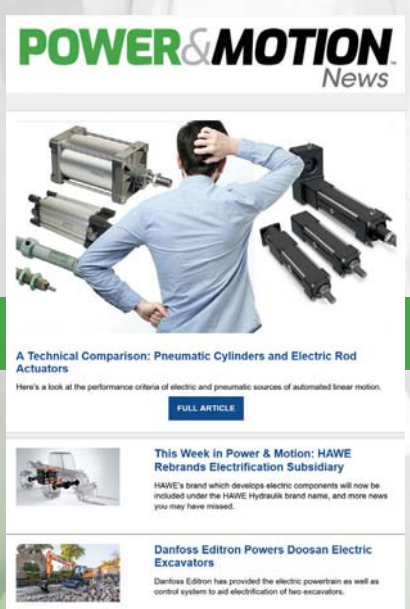

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ENDEAVOR BUSINESS MEDIA

[News]

by Sara Jensen, Executive Editor

Machine Vision Market to Grow Through 2028

The global machine vision market is forecast to grow 6.4% through 2028, driven by increasing automation in various industries.

In 2024, the global machine vision market is expected to make a turnaround and record single-digit growth of around 1.4% according to recent data from market intelligence specialist Interact Analysis.

This comes after a slower year for the market in 2023 where total revenues reached $6.3 billion, down slightly from the $6.5 billion recorded in 2022. Despite continued growth of automation – a key driver for the use of machine vision systems – price pressures presented challenges for vendors in 2023.

Interact Analysis expects these price pressures to persist through the first half of 2024 before order books begin to refill in the second half of the year, hence the lower growth rate projected for the year. Recovery for the machine vision market is expected to start in 2025 and continue through the decade which the research firm says is in line with its predictions for manufacturing and machinery production growth.

The firm is forecasting that between 2022 and 2028 the global machine vision market will grow by an estimated CAGR (compound annual growth rate) of 6.4%. Revenues for those working in this sector will increase from $6.5 to $9.3 billion during this time. Continued implementation of automation in various industries will help drive this growth.

Positive Conditions for Machine Vision Market Will Vary by Region and Application

According to Interact Analysis' report on the machine vision market, the Asia-Pacific (APAC) region is expected to provide the most growth opportunity in the coming years because of its stronger customer base.

"Due to the stronger performance of end-customers in APAC, vendors in that region were expected to have had a better year than those with less exposure in 2023," said Jonathan Sparkes, Research Analyst at Interact Analysis. "In general, APAC suppliers – particularly those in China – took share from those who conduct more of their business in other global regions."

The applications in which machine vision components and systems are used will play a role in the market's performance as well.

Inspection is the dominant application for the machine vision market, accounting for over 40% of use cases in 2022 per Interact Analysis. This application segment will continue to be the top user of machine vision technology and is forecast to be worth about $3.9 billion by 2028.

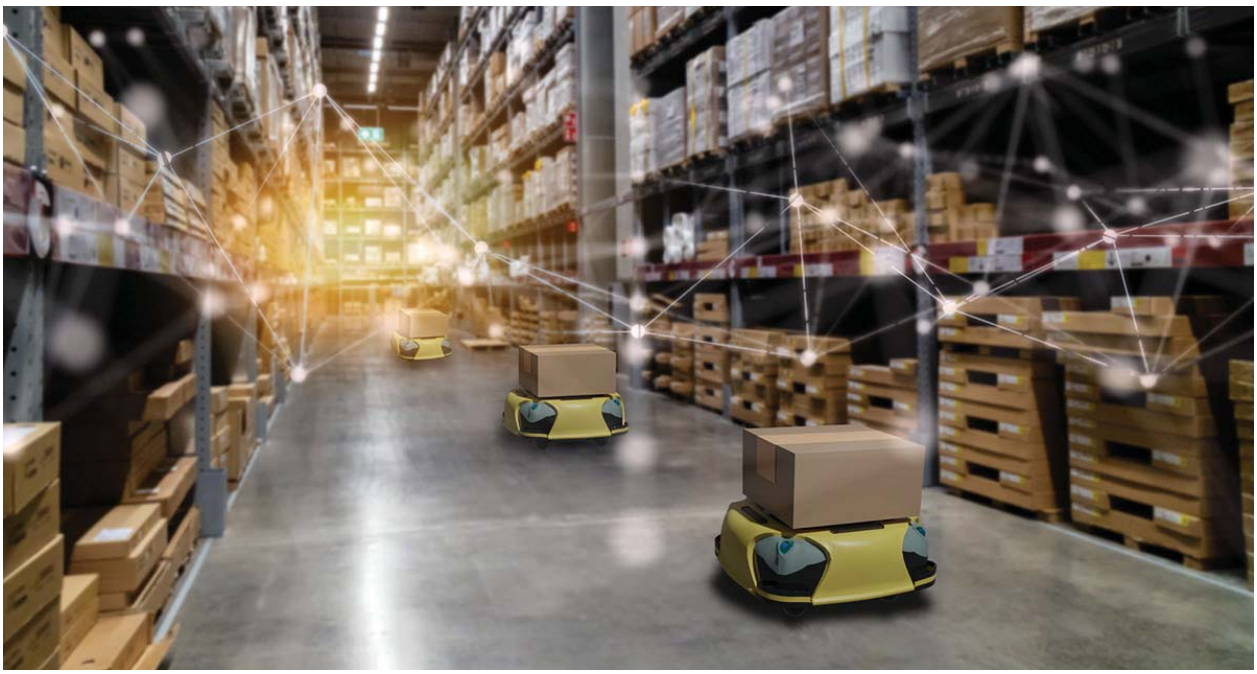
Interact Analysis is projecting autonomous driving applications to see the largest CAGR between 2022 and 2028, due in part to the strong outlook for mobile robots. These robots are already being put to use in various industries, particularly

WHAT IS MACHINE VISION?

Machine vision is a concept which brings together various hardware and software tools to help machines see objects. It uses images captured by one or more cameras to gather information and make decisions based on that collected data which may be relayed to other parts of a machine to tell it how to react – such as telling a robot's pneumatic gripper to pick up an object.

This makes it an important part of many autonomous systems and machines. It is commonly thought of as a technology for robots, both stationary and mobile, as it enables them to detect objects they may need to inspect, pick up or avoid while maneuvering around a facility.

But it can also be used for autonomous driving systems employed in passenger cars and heavy-duty on- and off-highway vehicles. In these applications, machine vision can be used to determine if there are objects in the surrounding area and signal to the vehicle if an evasive maneuver should be taken, such as applying the brakes.



The increasing use of mobile robots in warehousing, manufacturing and other industries will aid future growth for 3D cameras which help the robots safely maneuver around a job site. *172103095 © Ekkasit919 | Dreamstime.com*

manufacturing and warehousing, and their use will continue to grow as a means of helping improve productivity and overcoming the labor challenges facing so many sectors.

The research firm forecasts autonomous driving applications will achieve a CAGR of 20.8% through 2028. Bin-picking will present the second highest growth application with a projected CAGR of 19.2%. Continued deployment of industrial robots in various manufacturing industries will drive growth in this application area.

Sparkes noted there are three key vendors in the machine vision market which account for much of the sector's revenues. However, new companies continue to enter the market as well, bringing with them new technologies and application uses.

"Despite a plethora of mergers and acquisitions in recent years, the machine vision market is still considered fragmented. New vendors continue to enter the market, with over 200 active worldwide," said Sparkes. "We are seeing increasing activity from new vendors in China in particular, as well as in those territories where machine vision products are increasingly being used for autonomous driving and bin-picking."

3D Cameras to be Strong Driver for Market Growth

Within the machine vision market, Interact Analysis sees 3D cameras being the product type which will provide the strongest growth potential. This is due to the rising implementation of mobile robots and robotic picking, key users of 3D cameras.

While the machine vision market itself is forecast to grow 6.4%, 3D cameras are expected to achieve a CAGR of 13% through 2028, reaching a value of about $1.6 billion.

Time-of-flight and stereo-vision cameras are anticipated to provide the highest levels of growth. Both can be used to detect objects and are thus often used with mobile robots; therefore, the projected growth of the mobile robots market in the coming years will lead to improved market conditions for these two 3D camera types as well.

Although these two camera types are cheaper than structured light and laser triangulation 3D cameras, they have gained more market share in recent years. Interact Analysis is forecasting stereo-vision cameras will achieve a CAGR of 19% and time-of-flight options a rate of 17.3% through 2028.

The research firm sees continued price reductions being a key driver for the rising use of 3D cameras. This will enable manufacturers to use a single camera in place of several 2D versions while getting the same, if not better, detection capabilities and enabling more compact designs – leading to faster response times for robots as well.

New camera vendors are continually entering the market which is helping to bring down costs as well as improve technological capabilities.

Use of 3D cameras in autonomous driving and bin-picking applications will help this segment's future growth trajectory as well given these are the application uses with the largest growth potential for the overall machine vision market.

Interact Analysis reports the mobile robot market, where autonomous driving is currently most available, grew 33% in 2022 and further growth is expected in the coming years. The firm also notes that substantial year-on-year growth in sales for picking robots will help drive further expansion of the 3D camera market.

Overall, positive conditions are expected for the machine vision market as sectors such as manufacturing continue to increase their use of automation solutions. P&M

by Sara Jensen, Executive Editor

The 5 LEVELS of Autonomy in Off-Highway Equipment

With each increasing level of autonomy come new capabilities and opportunities to improve the productivity and safety of mobile machines.

Development of autonomous systems and vehicles in the off-highway equipment industry — a key customer segment for fluid power — is on the rise. Understanding the different levels of autonomy possible and the technologies involved ensures the design of an autonomous solution which best meets the needs of a given application.

As hydraulics and pneumatics are integral to the operation of construction, agricultural and other off-highway equipment, they often play an important part in and are directly impacted by the automation systems being created for this market (*see sidebar below*).

According to Peter Bleday, vice president of connectors and formerly head of Autonomy at Danfoss Power Solutions, there are three core problems autonomy is looking to solve in the off-highway equipment industry:

- addressing shortages in labor and skilled labor by improving machine and operator productivity,
- reducing rework and increasing first-time quality by performing precision tasks faster and more reliably, and
- reducing the risk of accidents and associated costs by improving safety.

Through development of operator assistance functions and eventually driverless vehicles, heavy equipment manufacturers and system suppliers hope to overcome these industry challenges by making construction, agriculture, mining, and other similar applications more productive and efficient.

AUTONOMY KEY DESIGN AREA FOR FLUID POWER

The 2023 edition of the National Fluid Power Association (NFPA) Technology Roadmap, which aims to guide development efforts for hydraulics and pneumatics, points to autonomy as a key customer objective for OEMs in mobile and stationary applications.

Within the roadmap, various capability improvements for fluid power components as well as research areas are outlined which could help achieve the technological goals required for autonomous systems and machines.

READ MORE about the development initiatives outlined in the 2023 roadmap: Assessing Future Design Needs for Hydraulics and Pneumatics at ***www.powermotiontech.com/21272646.***

◀ *GPS-based autoguidance in agricultural equipment keeps machines moving as needed, removing some of the physical burden from operators. Images courtesy Danfoss Power Solutions*

During the National Fluid Power Association's (NFPA) Fluid Power Industrial Consortium (FPIC) quarterly seminar on the topic of fluid power and autonomy, Bleday outlined the 5 levels of autonomy possible in off-highway machinery.

What are the 5 Levels of Autonomy?

Bleday said when talking about the levels of autonomy which are possible on a vehicle, it equates to how much automation is included. There are technically six levels of autonomy, but the first, Level 0, is no automation, leaving five actual levels of autonomy in which increasingly more autonomous capabilities are included on a vehicle or machine.

Level 1: Operator Assistance

The first level in which some automation exists, Level 1 autonomy, is simple operator assistance. For this level, Bleday said to think of features in a passenger car where it could be something as simple as anti-lock brakes. "You are still making the physical and mental decision to press on the brake pedal, but the car itself has that anti-lock feature to prevent you from locking the brakes," he explained. "It allows for you to be a safer operator but you're still making the mental decision and the physical action to step on the brake, so you control that decision-making process."

In off-highway equipment, this is often seen through steering technology — which often utilizes hydraulics — where the operator still controls most functions, but steering can be done by the machine as directed by the operator. This technology has been in agricultural equipment for years, helping farmers to maintain an accurate driving path through crop rows.

Level 2: Partial Automation

The second level of autonomy, partial automation, means there are certain circumstances in which the machine will control functions such as steering, accelerating and braking but an operator is still directing and monitoring actions. Bleday said GPS-based autoguidance, a common feature in agricultural equipment, is a good example of this as well.

When thinking of a passenger car, a feature like cruise control is a good example of Level 2 autonomy. Vehicle speed is maintained by the system, but the operator is still responsible for switching lanes or other vehicle controls. "The operator is still responsible, still making all the directions, still making all the active decisions around the vehicle but you're now removing some of the physical load on the operator from not having to press the acceleration pedal, etc.," he explained.

Level 3: Conditional Automation

Bleday said moving to Level 3 autonomy, referred to as conditional automation, is when machines can start to make some decisions for the operator. At this level, more complex actions can be controlled and executed by the machine so an operator can focus on executing his or her work accurately.

For example, an obstacle detection system can monitor the surrounding area and the operator can tell the machine to follow a path. This frees the operator to instead focus attention on the implement attached to the machine and the work which needs to be done with it. If an obstacle is detected, an alert can be provided or the machine stopped, taking over more of the decision-making process, said Bleday.

"These are more complex actions [but] the operator is still in the machine and is the final arbiter of safety," he explained. "But the machine is able to now start to take some of that mental decision load off of the operator as well as the physical decision load that we talked about in Level 2."

Bleday said most of the industry is currently between Level 1 and 3. "There are some OEMs that are pushing toward Level 4, but it's in specific use cases."

Level 4: Supervised Automation

At Level 4 autonomy, Bleday said there is a slight deviation from the SAE definition which is more focused on the on-highway sector. For the off-highway equipment industry, Level 4 is referred to as supervised automation or sometimes high automation.

Machines with Level 4 automation capabilities can operate without human input or oversight and multiple autonomous machines can work together under supervision of a human.

"The way we think about it is one operator is in the field, on the site or in the area and can be managing multiple machines," said Bleday. "Ninety-five to 97% of the time that machine is

With Level 2 autonomy, operators are still responsible for directing and monitoring operations, but certain machine functions, such as steering, can be automated.

capable of doing its job and then those small percentages of time where it can't, the machine stops and flags the operator for assistance whether that be through some kind of remote control or the operator getting in the cab."

Because of those instances, he does not see operator cabs going away any time soon. "On a lot of these vehicles I think, overall, you'll still see the need for supervision and some operator driving during edge cases, even something as simple as driving or backing off of a truck might still require an operator [in the cab]," he said.

Level 5: Unsupervised Automation

The ultimate goal for many OEMs is to reach Level 5, unsupervised automation. At this stage, a machine can operate without human input or oversight. All critical tasks, such as steering and work functions, are controlled by the machine. Level 5 is the point at which operator cabs may start to disappear from machines.

To date, mining is the most common application where you see this level of automation being applied. Companies such as Caterpillar and Komatsu have had fully autonomous mine trucks in operation at mine sites around the world for over a decade now. For their machines, there are humans in command centers a distance away from the site who monitor the vehicles as needed — but it demonstrates what is feasible in off-highway applications.

"Overall, I think most industries are going to stay around Level 4 where there still will be an operator or at least some supervisor in the field," said Bleday. This is due to the regulatory environment as well as the fact that for some construction contractors or farmers, they have a single revenue stream they use their equipment for and so want someone there supervising it to ensure no issues occur.

> "Overall, I think most industries are going to stay around Level 4 where there still will be an operator or at least some supervisor in the field."

The Difference Between On- and Off-Highway Vehicles

For Levels 4 and 5 where more unmanned operation is possible, Bleday noted there are some key differences between on- and off-highway applications which should be considered. Automation systems for on-highway vehicles need to solve for every problem that could be encountered everywhere. "These are called edge cases, all the things that happen 0.1% of the time that still need to be solved for," he explained.

Danfoss is researching and developing autonomous systems for a range of off-highway equipment such as soil compactors (pictured) which present a good use case for autonomy due to the defined number of tasks these machines do.

However, for off-highway applications like agriculture there is still complexity, but the environmental conditions are more known. There are typically certain times of the day or year which crops are harvested and there is relatively more uniformity from one field to the next which helps remove a lot of the uncertainty on-road applications encounter. "[This] means that the problem of automating the vehicle to the point where the operator can come out of it and the safety case around that is just a little bit easier to do. Not necessarily easy to do, but easier than those on-highway cases," said Bleday.

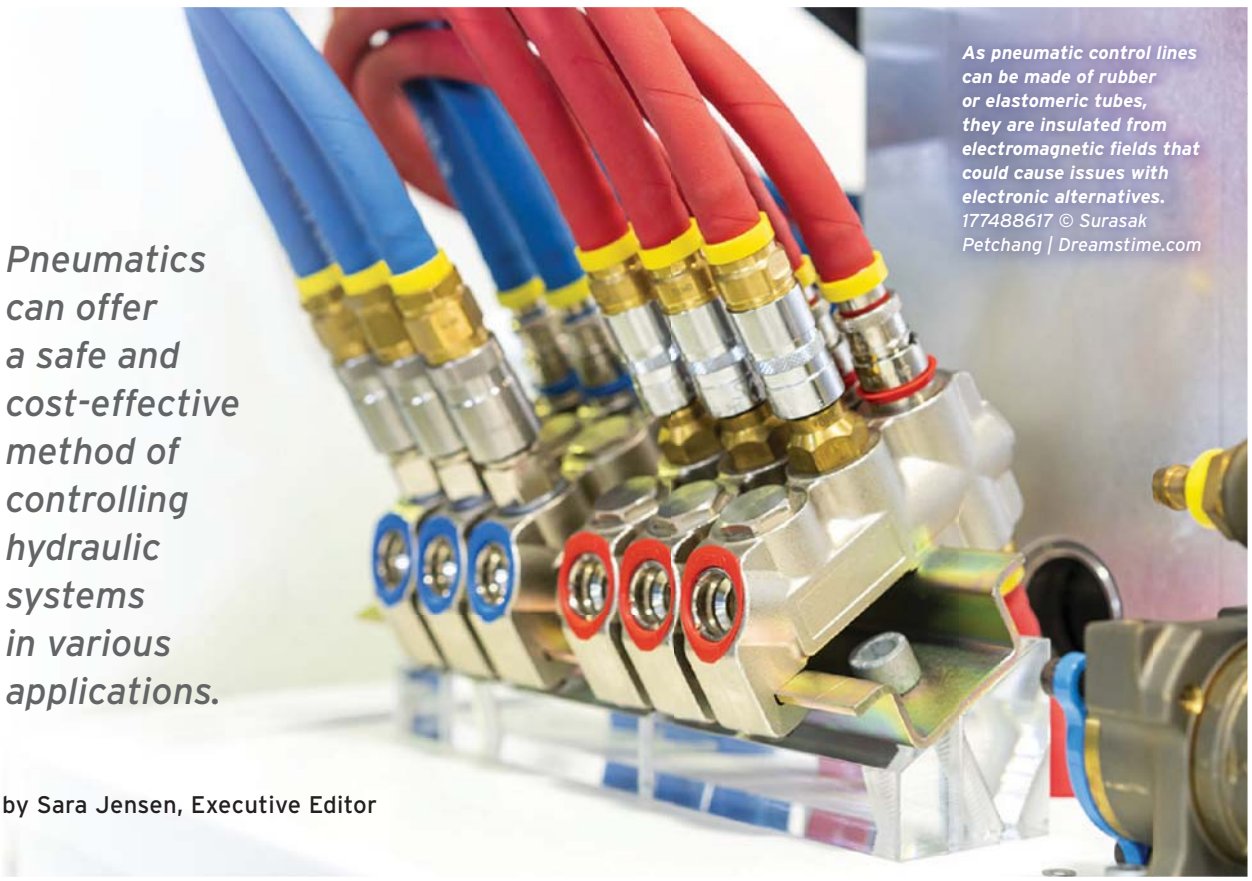
In addition, he noted the speeds at which agricultural machines operate are slower, which helps with implementation of automation systems in this market as well compared to on-road.

"The way we like to think about it is when automating a vehicle, you're automating the tasks that a vehicle does, not necessarily the vehicle [itself]," he said. "So, if the vehicle does one task, let's say in this case a soil compactor — it manages its route, it compacts soil and has a certain number of passes, maybe there's a compaction management system — that's a pretty well defined number of tasks that vehicle does. And as you move through the automation of each of those tasks, all of a sudden, the vehicle looks more and more capable of being fully autonomous.

"[In comparison] a car is ultimately just a utility vehicle, and can do any number of tasks," he continued. "That can be much more complex in its design domain."

Ultimately, the goal with each additional level of autonomy is to enable machines to do everything an operator does to help increase productivity and safety which in turn can help alleviate some of the burden caused by the labor challenges facing the off-highway equipment market. The drive to ever-increasing levels of autonomy is leading to new technological needs and development opportunities for fluid power and related markets. **P&M**

Pneumatic Control for Hydraulic Systems: Benefits and Applications



As pneumatic control lines can be made of rubber or elastomeric tubes, they are insulated from electromagnetic fields that could cause issues with electronic alternatives. 177488617 © Surasak Petchang | Dreamstime.com

Pneumatics can offer a safe and cost-effective method of controlling hydraulic systems in various applications.

by Sara Jensen, Executive Editor

Pneumatic control is one of several methods which can be used for hydraulic systems. "Every hydraulic system requires some sort of control system," said Steve Weber, Regional Application Specialist at Sun Hydraulics.

These can include manually actuated valves or electrically actuated solenoid valves — commonly referred to as electrohydraulic valves — both of which can be switching or proportional. Commands are sent from human machine interfaces (HMI) such as electronic joysticks and programmable touchscreens as well as programmable logic controllers (PLCs) or industrial computers.

"Another means of controlling a hydraulic system is pneumatics," he said. "Benefits from using pneumatics range from convenience to safety."

The method chosen typically depends on which best suits the application at hand. Understanding when to use pneumatic control and the benefits it can provide can help determine if it is the right option for controlling a hydraulic system.

Pressure Requirements Determine When Pneumatic Control is the Right Choice

In a pneumatically controlled hydraulic system, an external pneumatic pressure signal controls the system's hydraulic pressure, providing the same function and performance as hydro-mechanical or electro-hydraulic control options.

Knowing the pressure and how well the pneumatic pressure is regulated are the key determining factors when deciding whether to use pneumatic control for hydraulic systems, said Weber. In addition, it is important to know the hydraulic pressure being controlled.

"It is key to know the hydraulic system pressure throughout the operation of the machine and to know the regulated pneumatic pressure," he said. However, one of the biggest challenges is "understanding how the hydraulic pressure dictates the pneumatic pressure required for proper function of the pneumatically controlled hydraulic valve.

"Pneumatically controlled hydraulic valves typically require a minimum of 50 psi and up to 100 psi pneumatic pressure,"

he explained. "But this is dependent upon the hydraulic pressure."

Weber noted that Sun Hydraulics offers various pneumatic actuated relief and directional control valves for use with hydraulic systems. Direct-acting versions are available for flows up to 2 gpm (7.5 lpm) while the pilot-operated relief valves are for flows up to 200 gpm (760 lpm). "Pressure ratios for pneumatically controlled hydraulic relief [valves] are 50:1 and 75:1 allowing for the readily available pneumatic pressure to control up to 5,000 psi hydraulic pressure," he said.

Advantages of Using Pneumatically Controlled Hydraulic Systems

Pneumatically controlled hydraulic systems can benefit many applications, especially those where safety may be a concern or where pneumatics is already being utilized.

Weber said many industrial machines rely upon pneumatic controls. "These machines may be hydraulically actuated but also have some pneumatics on them," he explained. "It can sometimes be more convenient to control the hydraulic system with pneumatics in this example over introducing a new control system such as electro-hydraulic valves."

In this situation, there is no need to install additional equipment as all necessary components for pneumatic supply are already available. This not only eases implementation for machine owners but also reduces potential installation costs. An electro-hydraulic system, on the other hand, would require the installation of electrical wires, power supplies and other accessories which could drive up costs.

However, pneumatically controlled systems tend to have a slower dynamic response time compared to electro-hydraulics which should be taken into account based on the application's requirements.

Weber said pneumatic control for hydraulic systems can also be the right marriage of technologies for hazardous environments where the use of explosion proof coils for electro-hydraulic valves would be required. "These ATEX/CSA rated explosion proof (EX) coils can be very expensive," he said. "The use of pneumatic control might be a cost-effective option that provides the needed safety in these environments."

Examples of these applications outlined by Sun Hydraulics include:

- oil drilling platforms
- oil and gas handling equipment
- chemical industry equipment
- dust-laden atmospheres (grain elevators)
- vehicular lifts
- sawmills.

As there are often combustible or explosive materials present in these types of applications, electrical devices used in them are required to meet "Intrinsically Safe" or "Explosion Proof" standards. This means they are designed to prevent heat or a spark sufficient to cause an explosion, even if the device is worn or damaged.

"Applications where heat generation is problematic from high duty cycle use of a solenoid coil might be solved with pneumatic control," said Weber.

Environments with strong electromagnetic fields can be a concern as well if using electro-hydraulic control. Large currents or "noise" can be created which can lead to false signals being sent to sensitive electro-hydraulic devices.

Pneumatically controlled systems can offer a better fit in hazardous applications because of the lower cost associated with the pneumatic lines compared to the electrical wires and other accessories. They are also not susceptible to the noise caused by electromagnetic fields because pneumatic control lines can be rubber or elastomeric tubes which makes them an electrical insulator.

In addition, Weber noted that some pneumatically controlled hydraulic valves can offer a size advantage over solenoid operated hydraulic valves. This could benefit the trend toward more compact hydraulic system designs as machine space constraints increase, particularly in mobile applications.

"Virtually any application that uses both hydraulic actuators and pneumatic controls could possibly marry these two systems by using a pneumatically controlled hydraulic valve," he concluded. P&M

BENEFITS OF USING PNEUMATIC CONTROL

Pneumatic control for hydraulic systems can offer several benefits over electro-hydraulic control, including:

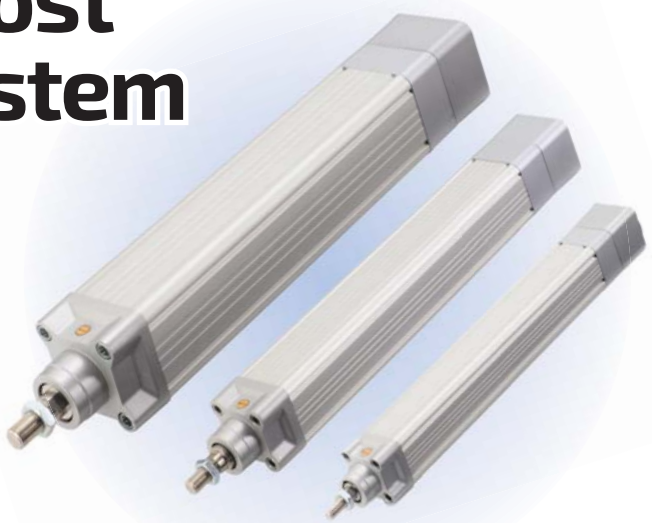
- cost-efficiency,
- simplified installation,
- reduced space claim, and
- increased safety.

Sun Hydraulics' air-controlled hydraulic pressure control valves use an external pneumatic pressure signal to proportionally and/or remotely control hydraulic pressure. *Sun Hydraulics*

Choosing the Right Linear Actuator to Boost Automation System Performance

Understanding available electric linear actuator types and their performance characteristics ensures the right option is selected for a given automation system.

by Niklaus Roethlisberger and Linda Schwartzen



Emerson's AVENTICS Series SPRA are an example of electric rod-style linear actuators which can offer the enhanced load capacity, accuracy and reliability that manufacturers need to maximize productivity. *Emerson*

Electric linear actuators are valuable and versatile systems that provide fast, efficient and accurate movement of products and materials in today's high-speed factory automation systems.

Manufacturers offer multiple electric linear actuator models for both single-axis and multi-axis applications. These actuators use a range of designs and motion components to serve different load, accuracy and speed characteristics.

Choosing the right electric linear actuator calls for a deeper understanding of the options available in the industry. With that understanding, original equipment manufacturers (OEMs) and end users can match a selected actuator's capabilities to the long-term efficiency, productivity and control each machine or production line requires.

Growth of Electric Linear Actuators in Automation

There is steady growth in the use of electric linear actuators in highly automated industries. Electric linear actuators are widely used in automated production platforms with high-speed throughput requirements and repetitive linear motion cycles.

Some heavier industries, such as automotive and tire manufacturers, are in the early stages of adding electric actuators to their production platforms while continuing the use of pneumatic actuators in certain applications and machines.

Automation-intensive segments such as food processing and packaging use a hybrid mix of both pneumatic and electric actuators to drive linear tasks in their machines. In industries such as semiconductor, pharmaceutical and electronics production, electric linear actuators provide very stable and vibration-free linear motion combined with highly accurate and repeatable endpoints, a critical requirement for automated production in these segments.

One main advantage electric linear actuators offer is advanced motion control. Powered by electro-servo drives and motors and connected to production system PLCs, electric linear actuators can provide more agile and flexible control of critical motion factors such as speed, cycle time, endpoint accuracy and repeatability.

In addition, with the built-in power regeneration capabilities common in today's servo drives, linear actuators can offer automation system designers improved energy efficiency. Smart servo drives combined with sensors embedded in the modules supply crucial real-time data on actuator performance, efficiency and repeatability.

This is critical data manufacturers now routinely require from technology used in their systems to help advance digital transformation in their operations.

Assessing Actuator System Design Options

To select the right electric linear actuator, it is helpful for automation system designers to examine and better understand the different kinds of linear actuator technology available in today's marketplace and the capabilities each option provides.

In general, electric linear actuators can be easily categorized according to their drive mechanics. There are three broad categories of electric linear actuators: belt-driven modules, screw drive or spindle drives and linear motor actuators.

Each has specific speed, load bearing, accuracy and other functional characteristics that guide actuator selection, based on specific manufacturing requirements.

Toothed Belt-Driven Actuators

A belt-driven actuator has an electric drive that powers a toothed rotator at one end of the module. This model converts rotary motion to linear motion by means of a toothed timing belt connected between two pulleys at either end of the drive.

Belt-driven modules work well when the linear sequence calls for medium repeatability, approximately 0.05 mm in motion, although higher repeatability can be supported with the use of integrated direct measuring system sensors.

Typically they can support moving medium-sized loads up to 300 kg. They also work well with larger strokes and sequences requiring a motion velocity greater than 5 m/s. Belt-driven linear modules are widely used in packaging applications to transfer products from one production line to another; they are also used in automated factories producing automotive parts like electric motors.

Leading suppliers offer these systems in a wide range of profile sizes (profile widths) and lengths, making them a modular option for multiple applications. Belt-driven electric actuators are also well-suited for building multi-axis systems such as pick-and-place and Cartesian motion systems.

Spindle or Screw Drive Actuators

In these systems, a spindle or screw in the center of the actuator converts the rotary motion to linear motion to move the load. They provide very high rigidity and low deflection, enabling greater endpoint accuracy with each duty cycle, for applications requiring approximately 0.02 mm repeatability.

These actuators support low to medium dynamics for applications requiring velocities up to 1.5 m/s. Their strength and rigidity also make them highly suited for placement and pressing applications where high force is needed, such as securely inserting an electric component into a larger assembly, such as an electric vehicle battery and material joining. They are also a good choice for vertical applications.

Direct Drive Actuators

In these modules, the belt or spindle is replaced with an electric linear motor that moves the module's carriage directly, rather than converting rotary to linear motion. They support very high endpoint accuracy, up to 0.01 mm, in part because the force is directly implemented at the moving part (carriage) with no elastic components in between (e.g., the rubber toothed belt).

This direct control also makes very complex start/stop, forward/backward motion sequences possible by programming the linear motor controller. It also supports the broadest range of strokes and velocities up to 10 m/s, as well as very slow and constant movement — which can be a requirement for moving very delicate electronics or other products that are susceptible to damage (e.g., laser applications or printing to achieve a constant result).

Toothed belt-driven actuators work well with larger strokes and sequences requiring a motion velocity greater than 5 m/s. *206853755 © Surasak Petchang | Dreamstime.com*

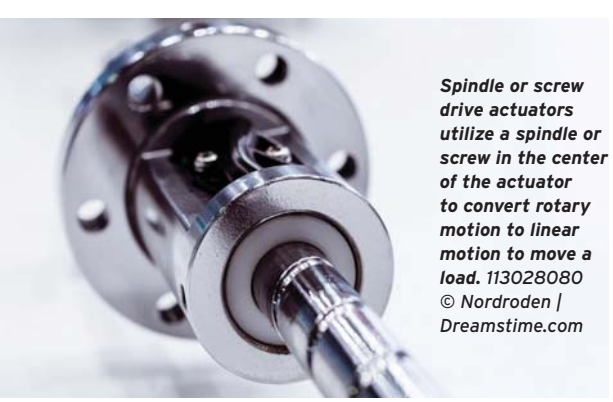
Direct drive actuators are often available in very compact sizes, making them a good option for production tools such as semiconductor fabrication systems that need to conserve valuable floor space without sacrificing performance.

Guidelines for Optimal Actuator Selection

Every automation machine and production line has unique operational and performance requirements, including the unique specifications for linear motion and transport. Since no two machines are identical, several best practices provide useful criteria automation system designers can use to guide actuator selection.

Automation OEMs and end users should first clearly define what task each actuator must perform in a machine or production line. That requires defining the motion profile for each actuator — and in some complex automated assembly systems, different process steps will call for different actuators with specific capabilities.

A linear actuator motion profile defines key parameters such as load — how much a component or product weighs — as well as the dynamics of the motion: how fast the module accelerates and moves the load with each duty cycle. The moving mass must also be calculated; this includes the material or component being moved, along with the total mass of the actuator, cabling,



Spindle or screw drive actuators utilize a spindle or screw in the center of the actuator to convert rotary motion to linear motion to move a load. *113028080 © Nordroden | Dreamstime.com*

integrated measuring devices, end grippers and other elements that make up the total load to be moved.

The stroke must also be defined: what is the distance the load must be moved and with what force; this last parameter is especially important if an actuator needs to firmly place or insert a component into a larger assembly. When assessing the force, it is important to factor in the direction of movement: will the actuator be moving product horizontally, vertically or at a certain angle?

Along with these other factors, defining the duty cycle is critical for selecting the most reliable actuator based on the expected long-term performance. For example, there are now modules available with a guaranteed 40 million duty cycles; these data points can help with rapid, high-throughput motion sequences. Within the duty cycle, pause times must also be considered. There is a big difference between actuators that move constantly and actuators that only move during one shift. Additionally, pause time during an individual cycle is important to note. An example of this could be one actuator needing to wait for another axis or process time.

The Afag SREH-50 IOL smart rotary module is an innovative and compact electric linear actuator that features an integrated controller and planetary gearbox for more sophisticated linear motion profiles. *Afag*

The Afag SGE-40-P-IOL smart electric gripper can grip up to eight different workpieces. The SGE-40-P-IOL provides four-stage adjustable gripper force through IO-Link for easy adjustments to sensitive workpieces. *Afag*

Once defined, the requirement profile gives automation designers the critical criteria for choosing the optimal electric linear actuator for each part of a new machine or assembly line. It is also important to recognize that in some motion applications pneumatic actuators may provide an equally efficient and cost-effective solution.

In addition, electropneumatic hybrid linear actuators can provide a versatile technology that combines the benefits of electric linear actuators and pneumatics. For example, when combining multiple belt-driven linear actuators into a Cartesian handling system for a pick-and-place application, pneumatics may be the most efficient way to actuate the gripper at the end of the Z-axis module in the system.

Working With the Right Actuator Portfolio

Once the requirement profile and linear actuator models are defined, choosing the right supplier is the next critical step.

It's important to assess the depth and breadth of each supplier's product lines. Does their portfolio include electric and pneumatic linear actuators, to provide flexible options? Can they provide complete linear solutions that include controllers, cabling, end effector grippers and adaptor plates when needed?

Today's leading suppliers configure the physical interfaces of their equipment so they can be easily combined together into multi-axis systems when needed. They also offer user-friendly online configuration and ordering tools to help system designers select and configure their modules based on the functional and performance requirements for each linear axis.

When assessing a portfolio, it's also important to review a company's ability to innovate. For example, one company recently launched a pioneering compact rotary actuator with the controller integrated into the module. This design saves control cabinet space and improves the motion control capabilities in the system.

Electric linear actuators provide an efficient and versatile tool to help create sophisticated production systems that deliver the performance manufacturers need. The range of electric linear actuator technologies now available gives automation system designers the freedom to choose and configure the right actuator each machine or production line needs. P&M

This article was written and contributed by Linda Schwartzen, product marketing manager for actuators, Emerson, and Niklaus Roethlisberger, product manager for actuators, Emerson, Afag Automation AG.

Electrohydrostatic Actuation Captures the Best of Hydraulic and Electromechanical

Electrohydrostatic technology brings together the high force benefits of hydraulics with the energy efficiency of electromechanical devices.

by Sara Jensen, Executive Editor

Hydraulic actuation has existed for a long time and continues to provide the power density required of many applications. But in recent years there has been a push toward electromechanical actuation options because they are considered to be more energy efficient and there are no issues with oil leakage — but this technology has its drawbacks as well.

Electrohydrostatic actuation, on the other hand, brings together the best of both technologies said Dave Geiger, Engineering Manager, New Business Capture at Moog Inc. "It offers you all the benefits that electromechanical [provides and] it also offers you all the benefits of hydraulic actuation."

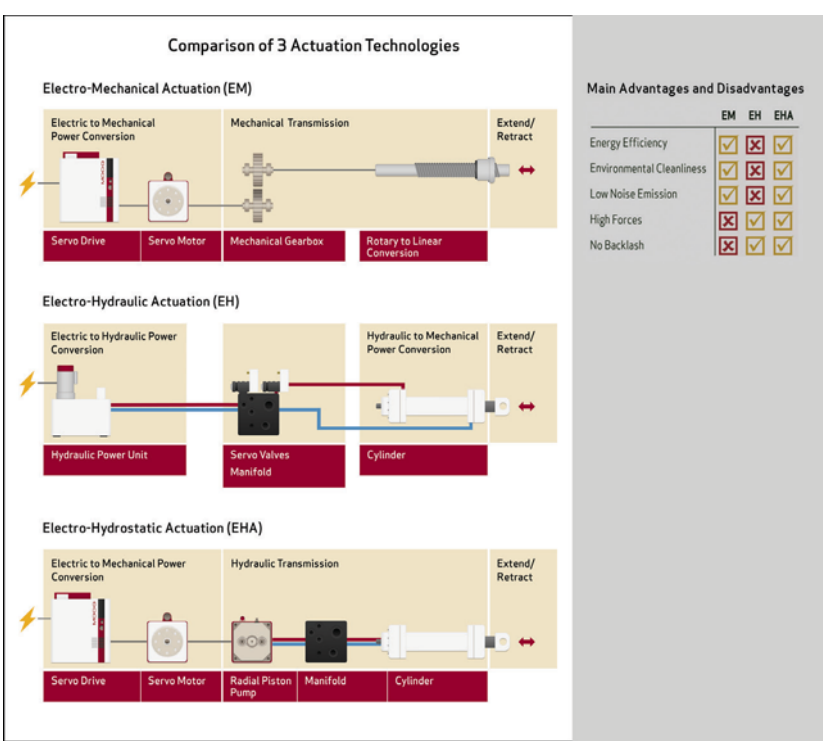
While more costly than electromechanical options, he said that if you need to capture the best of both worlds, electrohydrostatic is your best choice.

Electrohydrostatic Actuation Ticks all the Design Boxes

Geiger explained that electrohydrostatic actuation technology works similarly to electromechanical actuation in that a bidirectional motor controls the linear or rotary motion of the output device (i.e., an actuator). The difference is that electrohydrostatic technology uses a hydraulic transmission to transfer motion versus a mechanical transmission.

"So, it's a hydraulic transmission between the output of the actuator and the motor itself," he said.

Electrohydrostatic actuators combine the high force and durability benefits of hydraulics with the energy efficiency, low noise and environmental cleanliness of electromechanical devices. *Images courtesy Moog Inc.*



This comparison chart shows the technology differences between hydraulic, electromechanical and electrohydrostatic actuation devices as well as the pros and cons of each.

Compared to purely hydraulic or electromechanical actuation, Geiger said electrohydrostatic technology ticks all the boxes in the five main categories designers grapple with when developing motion control systems:

- energy efficiency
- environmental cleanliness
- low noise emissions
- high forces and
- zero backlash.

Hydraulics are not known for being particularly energy efficient — though there is a lot of development effort in this area currently — and the potential for oil leaks tends to negate their environmental cleanliness. They are also noisy, but again there are developments in progress to reduce their noise levels. But hydraulics are very good at providing high forces and do not create backlash which is not a good thing to have when trying to create precise motion control, said Geiger.

The shift to electromechanical systems came about because hydraulics are lacking in the first three categories, especially energy efficiency and environmental cleanliness which have become more important factors today than they were in the past. While electromechanical actuation offers the benefits of energy efficiency, low noise emissions and environmental cleanliness, this technology lacks the ability to provide high forces and not have backlash in the system.

Geiger said this is where electrohydrostatic comes in because it performs well in all five categories as it brings the beneficial aspects of electromechanical technology together with those of hydraulics.

How to Choose the Right Actuation Method

Understanding your cost parameters and application requirements are key factors to consider when determining which type of actuation technology to use.

For those who are cost conscious and are less concerned with energy efficiency and environmental impacts, then hydraulics are the route to go. "It is still the lowest cost [option] on the market…[and] it is the most readily available solution, there is so much product out there you can choose from," said Geiger.

If cost is still a factor as well as energy efficiency and the environment, then an electromechanical actuation system is likely the best fit.

Electrohydrostatic actuation comes into play when energy efficiency and the environment are important to an application, but an electromechanical device will not meet its high force and durability requirements.

"For electrohydrostatic, when the customer is really concerned about the environment and energy efficiency but can't make it work with an electromechanical solution, that's where the electrohydrostatic [solutions] come in," said Geiger.

"And typically, the reason [the customer cannot] make it work is because it is in an application that requires extremely high forces, or extremely high durability requirements [because] there's maybe a lot of shock loading on the actuator. And then that's where we would say we need to go into an electrohydrostatic application; that is where it is really best suited."

Geiger said Moog takes a technology neutral approach when working with customers as it offers all three actuation technologies and believes in recommending the best option for the application.

Market Adoption Continues to Grow for Electrohydrostatics

Electrohydrostatic actuation has been proving itself in various industries for many years, and continues to gain market share in those looking for a combination of high forces, energy efficiency and reduced environmental impact.

Geiger said Moog has been using the technology since the 1980s when the aircraft industry wanted to move to fly-by-wire — essentially running wires from where the actuation is happening — for its flight controls. Historically, hydraulic systems were used but the industry wanted to eliminate all the hydraulic lines involved due to their potential to leak and the efficiency gains possible by having fewer lines through which to transfer energy.

Electromechanical was not an option because while the required forces are low, the industry did not want there to be any risk of primary flight controls failing. He explained they wanted a by-wire (essentially an electric) solution but did not want mechanical devices such as screws or gearboxes to be part of it due to their potential to fail.

This left electrohydrostatic actuation as the option because from a transmission point of view, the technology works the same as a hydraulic system, said Geiger. "We [Moog] ended up moving that industry into electrohydrostatic for primary flight controls."

Industrial machinery is another sector shifting away from hydraulic actuation

HYDRAULIC VS. ELECTROMECHANICAL ACTUATION

The goal of hydraulic and electromechanical actuation is the same, but how each occurs is where they differ.

For hydraulic actuation, a proportional valve controls the rotary or linear motion of the output device. The problem with this technology said Geiger is it is not efficient due to the tremendous amount of pressure drops which occur across the valve and thus it consumes a lot of energy.

Electromechanical actuation, on the other hand, uses a bidirectional motor to control motion. The motor moves the output device of the actuator forward and back by changing the speed and the direction of that motor, he explained. And typically, a mechanical transmission is used such as a gearbox for rotary motion or a screw for linear motion. However, this technology is limited when it comes to force output and durability.

technology, due in part to greater environmental pressures to reduce energy consumption and emissions. Geiger said the move from hydraulics to electro-mechanical or electrohydrostatic — depending on the force needs of the machine — started slowly but has picked up the pace in recent years. "Now there's fairly quick movement," he said.

Because of the energy efficiency and high force capabilities possible with electrohydrostatic actuation, he anticipates rapid movement toward the technology over the next 10 years in the industrial machinery sector.

Geiger also sees opportunity for the use of electrohydrostatic actuation in the mobile construction equipment market as it transitions to battery-electric power systems. Often considered to be a slow adopter of new technology, the construction machinery sector has increased development of battery-electric options over the past 5 years.

He said these machines require the use of highly efficient actuation to minimize energy drawn from the battery which could otherwise shorten its operating time between charges. There are examples of compact machines using electromechanical actuation, such as the Bobcat T7X all-electric compact track loader developed in collaboration with Moog Construction.

The challenge, however, is the larger size machines with higher force and durability requirements which cannot be met with currently available electromechanical technology. Electrohydrostatic actuation might be the right solution though for these machines because it can provide the high levels of force and efficiency required.

"I think that's the big future right now for electrohydrostatic because it's such a big market and that industry is changing," said Geiger. "From a volume point of view and from a movement, I think that's going to be where we're going to see a lot of traction."

Electrohydrostatic technology is a key part of Moog's electrohydrostatic pump system which provides a complete system solution for easy integration into new or existing applications.

He noted that other heavy-duty mobile machinery like agricultural machinery and mining equipment could also benefit from this technology. And if fuel cells become the power source of choice in the future, electrohydrostatic systems will prove beneficial in these applications as well.

As with any technology, cost is always a factor. Geiger said certain industries

SHIFTING INDUSTRY KNOWLEDGE COULD CHANGE TECHNOLOGY NEEDS

The generational shift taking place in many industries is an aspect which could benefit the uptake of electrohydrostatic technology. Geiger said students coming out of school today likely won't have knowledge of hydraulics, unless in a fluid power program, but they will know how to design servo motor and electromechanical related technologies which will aid development and maintenance of these systems.

In industries such as construction there is a lot of familiarity with hydraulics because of the years of experience workers have had with the technology. That institutional knowledge is leaving though as older generations retire from the workforce which could make room for other technologies to enter the space.

The complexity of hydraulics has been a longstanding issue, as well, which alternatives could overcome. Electromechanical systems have fewer components and therefore it is easier to determine where an issue is occurring. Electrohydrostatic is similar in that sense, although it has the hydraulic transmission. But that transmission is distributed and simple he said, "because it resides on the actuation whereas in a normal hydraulic system, there's this massive manifold that feeds all these different actuators on the machine."

Being a distributed system makes it easier to determine the location of a fault because it happens on the actuation instead of a central system controlling many actuation points, he explained. "Whenever you have a distributed system like that, it is a lot easier to troubleshoot."

are very cost sensitive which can cause hesitation when moving to a different actuation technology.

Construction is one of these industries which he said is extremely cost sensitive. "That's one of the reasons that industry has stuck with classic hydraulics for such a long time because it was so cheap."

Cost pressures will be a huge challenge to overcome because electrohydrostatic systems are not cheap, said Geiger. But construction is an industry with high-volume potential "and we're hoping that through volume we can get those costs down," he concluded. P&M

New Automation Solution Provides Quick Maintenance Fix for Quarry Operation

When the controls for critical equipment failed at a rock quarry, an electrical contractor stepped up to design and implement a new automation system.

by Theodore Thibeau, Automation Specialist, Fleming Controls and Power Specialities, Inc.

Figure 1: A jaw crusher is an essential part of operations at many quarry sites, using compressive force to break down large pieces of material into smaller, more manageable parts. *Images courtesy Fleming Controls and Power Specialties, Inc.*

The jaw crushers which operate at rock quarries are designed to break down large materials safely and efficiently into smaller, more manageable sizes. These machines are important to the productivity of a quarry operation and any performance issues can bring operations to a halt.

As quarries are typically located in remote areas, it can be difficult to get service in a timely manner which can cause lengthy delays or quick fixes to be put in place which do not properly address the maintenance issue.

When a problem with crushing equipment occurred at one such site, Fleming Controls and Power Specialties (FCPS) based in Bryant, AR, was called to help get this crucial production equipment running reliably.

Determining Maintenance Needs for Jaw Crusher Automation System

FCPS was approached by quarry personnel to help repair the automation system of a jaw crusher when its controls and associated equipment experienced control system issues that caused operations to halt.

Initially, the quarry operator hardwired a series of relays and switches allowing limited operations to resume in a manual mode while the troubleshooting process was underway. The jaw crusher and associated devices were originally built using a Modicon programmable logic control (PLC)-based system for control and monitoring, but the quarry did not have in-house personnel to support this legacy system. In fact, they did not even have access to the PLC program, which is not uncommon when dealing with original equipment manufacturers (OEMs).

Therefore, running the crusher manually was a stopgap option that severely limited operational throughput. An initial attempt was made for external support to replace the PLC, but this was found to be cost-prohibitive, so manual operation continued. As activity increased at the quarry — requiring the jaw crusher to ramp up production to multiple days per week — the operators knew a better solution was needed.

This is when the quarry approached FCPS to aid in the repair of the jaw crusher's automation system. As an electrical contractor specializing in industrial design, installation, and repair services, FCPS quickly got to work assessing the client's needs.

The FCPS and quarry teams quickly determined the best solution would be retrofitting new automation starting from scratch.

Choosing the Right Solution for Performance and Budget Requirements

The first decision for FCPS was selecting the automation platform. The quarry operator valued reliability, but they also needed a cost-effective solution since they did not have ready budget allocated for equipment automation replacement, so the maintenance budget would be stretched thin.

Although FCPS typically uses another major automation brand, the team decided that to meet the budget and delivery constraints for the jaw crusher project they would be better served by using Auto-

mationDirect PLC and human-machine interface (HMI) products *(Figure 2)*.

The selected PLC was a BRX stackable micro brick form factor that does not require a base or backplane. This compact size made it ideal for retrofit within the existing control panel footprint. The BRX line is incredibly versatile, with the functionality, processing power, input/output (I/O) interface, and communication protocols necessary for a modern automated industrial control system.

Additional I/O expansion modules easily snap onto the side of the BRX controller, which was useful for the jaw crusher application. HMI duties would be carried out by two C-more CM5 series color touchscreen units.

Initially, FCPS had some reservations about learning a new platform on a tight deadline, but ultimately, they found it to be an enjoyable challenge. Although there was a lot to learn, there was no shortage of support; the FCPS team was able to leverage tools from AutomationDirect and other industry PLC programming and HMI configuration experience to rapidly increase their comfort level with the BRX and C-more platforms.

The free software provided with both was intuitive and FCPS quickly developed the ladder logic and associated graphics objects.

Automation Technology Selection Eases Integration and Support

As the old controller was removed and the new PLC was installed, it was clear that the existing I/O field wiring was too short to reach. Rather than spend hours replacing it all, ZIPLink pre-wired connection cables and modules were utilized to minimize the need for intermediate connections or splices.

The ZIPLink wiring solution simplified the I/O termination process and reduced the opportunity for wiring errors by extending field connections away from the I/O modules with a connectorized cable and easily accessed field terminals.

While the majority of I/O in the system was discrete, the crusher automation

Figure 2: A new control system for the jaw crusher was built around the AutomationDirect BRX PLC, a versatile stackable micro brick platform with I/O expansion modules. Because the existing field wires were too short, a preconfigured ZIPLink cabling system was used to facilitate connections.

relies on a 4-20 mA input from each of the two crusher motor current transformers (CTs). These signals indicate equipment loading and are used to modulate the material feed rate.

When FCPS encountered a question regarding the integration of these analog inputs, they placed a call to AutomationDirect's technical support team. In less than an hour, a highly knowledgeable representative returned the call and resolved the issue. This positive experience and swift solution further bolstered FCPS's confidence in their decision to choose AutomationDirect as the automation supplier for the project.

With user experience in mind, FCPS prioritized simplifying the design so quarry employees could easily operate and maintain the new jaw crusher control system. The user interface follows this principle and features two HMIs.

The primary HMI is a 12 in. unit *(Figure 3)* with plenty of room to display all of the settings for the crusher controls as well as the status of pumps, motors, and the feeder inputs on a single screen. Alarms can also be viewed and managed from the primary HMI.

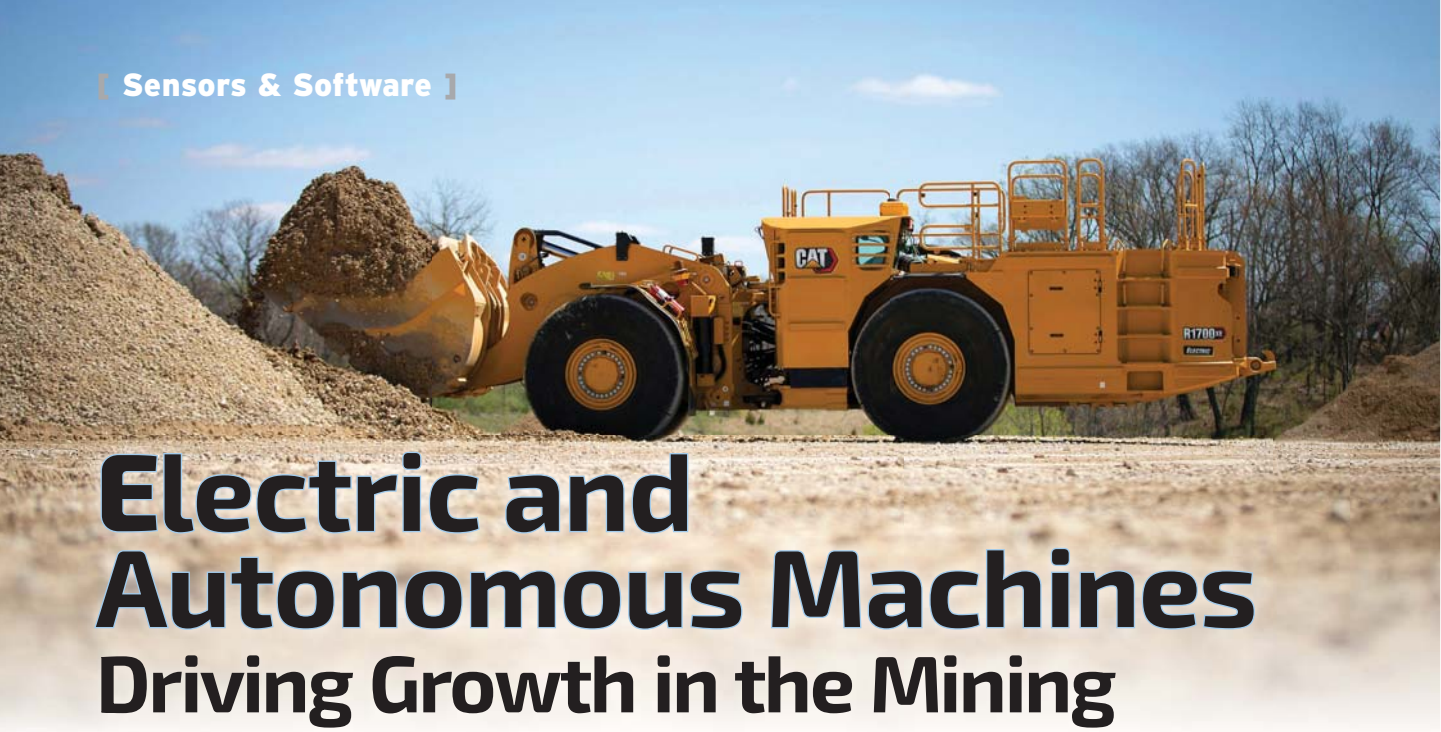
Due to the large size of the jaw crusher, a second HMI was added as a convenience for localized troubleshooting. The local HMI utilizes a smaller 10 in. color touchscreen and provides an easy way to manage alarms at the point of work without having to navigate back to the main control panel.

When developing the HMI screens for the jaw crusher, the pre-loaded drag-and-drop icons for pushbuttons and switches, as well as numerous tools and a simulator within the HMI software package, made configuration easy and efficient.

The success realized by FCPS using AutomationDirect products highlights the transformative power of innovative and fit-for-purpose automation solutions. To overcome challenges posed by outdated equipment with prohibitive support costs, the team found the choice of a new retrofit automation and visualization platform emerged as the ideal solution for the rock quarry application.

Robust product performance, unrivaled customer-centric support, and practical value are the types of benefits ensuring companies like FCPS can support their customers in a time of need. P&M

Figure 3: The primary user interface for the jaw crusher is built on the AutomationDirect C-more CM5 series 12 in. color touchscreen HMI. With space to display all the jaw crusher and feeder settings, the number of screens to navigate was reduced allowing operators to quickly confirm status at a glance.

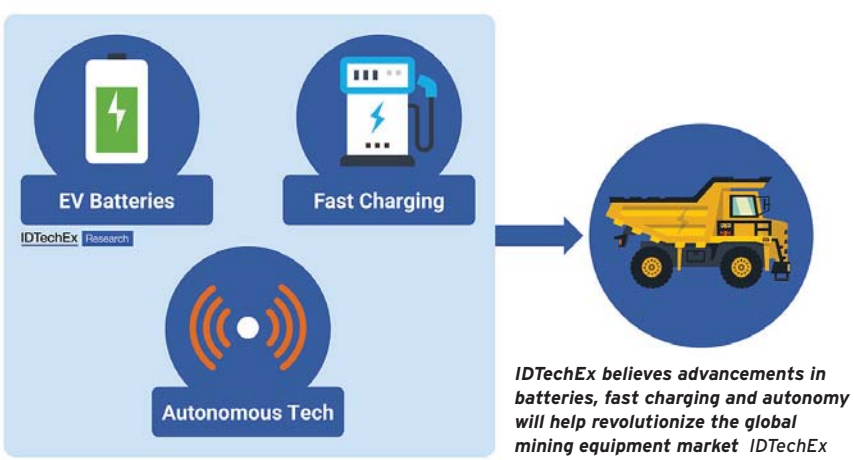


Electric and Autonomous Machines

Driving Growth in the Mining Equipment Market

The rise in demand for various materials, coupled with the benefits of reducing emissions and increasing productivity, is fueling the adoption of electric and autonomous machines which will aid future growth for the mining industry.

by Sara Jensen, Executive Editor



IDTechEx believes advancements in batteries, fast charging and autonomy will help revolutionize the global mining equipment market *IDTechEx*

The creation of electric and autonomous machines continues to be a key development and market driver for the mining equipment industry. With these types of machines, it is possible to reduce emissions and increase productivity which benefits the safety of those working in mining environments as well as the mine's ability to keep up with ever-increasing global demand for materials.

As the global population continues to rise and urbanization grows, demand for various mined materials such as metals is increasing which will drive growth for the overall mining equipment market. Growth in automotive production, mechanical equipment, infrastructure projects and the move toward electrification in various industries are all boosting demand for mining.

Allied Market Research, for instance, is forecasting the global mining equipment market will achieve a compound annual growth rate (CAGR) of 4.1% through 2032, reaching a total value of $200,892.3 million. The research firm is also projecting the undergrounding mining equipment market will achieve high growth of 4.9% to reach a value of $32,974.5 million by 2032.

Per the company's research, demand for mining equipment will be driven in part by a desire for more technologically advanced machines because of the many benefits which can be achieved to help mine more materials in a safe and efficient manner. The electrification and automation of mining equipment will be a key part of this.

Operational Costs Key to Uptake of Electric Mining Equipment

The electrification of mining equipment is not a new concept, but like

◀ ***The Cat R1700 XE underground battery-electric LHD includes onboard charging technology to help extend run times.*** *Caterpillar Inc.*

many other industries its prevalence in the market has grown in recent years as technology has advanced. IDTechEx is forecasting the electric mining vehicle industry to reach a value of $23 billion by 2044 due to the amount of development taking place for this sector.

Emissions reduction plays a role in the drive toward electric but is not the only factor. According to IDTechEx's research, the mining industry is responsible for 2-3% of global carbon dioxide (CO_2) emissions, of which almost half comes from the diesel engines used to power mining equipment.

However, there are many total cost of ownership (TCO) savings and safety improvements possible which will be bigger drivers for the industry's move to electric powered machines. The TCO aspect is especially important because mining equipment is a tool used to get work done and therefore needs to provide a good business case to an operation.

Fuel and maintenance costs associated with diesel-powered machines can be high. IDTechEx estimates a single 150-tonne haul truck can use over $850,000 worth of fuel in a single year. In addition, there are more wear points in the mechanical systems used within these machines. When they fail, it can take time to get spare parts because of the remote locations of mines. And should an unplanned downtime situation occur, it can be a very expensive situation.

Electric machines, on the other hand, tend to have lower maintenance costs associated with them because there are fewer wear points in the components and systems utilized. Energy costs are also lower for electricity — which may already exist at a mine, making it easier to install the necessary charging infrastructure as well.

Safety is also a benefit, particularly for undergrounding mining where eliminating emissions from the enclosed spaces in which machines and humans work is critical. Typically, expensive ventilation is required. Eliminating the need for that by using electric powered machines instead would help to lower costs for a mining operation. Heat and noise can also be eliminated from the working environment, helping improve conditions for personnel.

In its report on the underground mining equipment market, Allied Market Research said internal combustion engine powered machines will likely continue to dominate the sector due in part to the existing infrastructure and familiarity associated with them. However, it does expect electric machines to account for the largest growth, a CAGR of 11.0%, through 2032.

IDTechEx said electrification of underground mining equipment is where much of the emphasis has so far been placed for the market because of the safety and cost benefits possible. Electrifying underground machines is also more feasible

Electrification of underground mining equipment benefits the health and safety of those working in the confined spaces of underground mines. *S. Jensen*

OEM ACQUISITIONS WILL EXPAND BATTERY DEVELOPMENTS

There are many equipment manufacturers and suppliers working to expand electrification in the mining industry. In late 2023, Volvo Group and Komatsu announced their plans to acquire battery suppliers to aid their efforts.

Volvo acquired Proterra Inc., known more for its work in the transit bus sector but which has also developed battery-electric systems for other heavy-duty applications including off-highway machines. Already a strong player of electrification for on- and off-road vehicles, Volvo said the acquisition of Proterra would help to accelerate future developments.

Komatsu, on the other hand, acquired American Battery Solutions (ABS) which develops batteries for heavy-duty mobile and industrial applications. In its press release announcing the acquisition, Komatsu specifically noted it will use ABS batteries for mining equipment in North and South America where it is witnessing increased demand for electrification solutions. The acquisition will also aid battery developments for other off-highway equipment applications.

due to their smaller size, and thus lower battery power needs (up to 500 kWh), compared to surface mining machines.

Improved Battery and Charging Tech Will Aid Electrification Efforts

Further development of battery and charging technology will be necessary to ensure the continued uptake of electric mining equipment, particularly for larger size machines. Per IDTechEx, large machines such as mine haul trucks can require up to 2 MWh.

It noted in its research that batteries of this size have reached a point technologically at which they can meet the needs of the market and at a competitive price, and several companies continue to develop batteries capable of meeting the specific performance requirements of mining equipment.

While nickel manganese cobalt (NMC)) and lithium-ion phosphate (LFP) are the commonly used battery types at the moment, IDTechEx said research into other chemistries such as lithium-titanium-oxide (LTO), known for its faster charging capabilities, and sodium-ion (Na-ion) could benefit further electrification of mining equipment.

The ability to quickly charge electric machines will be a key aspect for greater adoption of electrification in the mining industry as well. Currently it can take several hours to recharge a machine, but OEMs and suppliers would like to get that time closer to what customers are used to when refueling a diesel engine — which is around 10-20 minutes.

Getting charge times associated with conventional plug-in charging closer to an hour or less would help achieve this goal. To do so, some OEMs are looking into multi-gun charging and megawatt charging. But IDTechEx noted in its research charging at the high rates associated with these systems can accelerate battery deg-

EXPANDING AVAILABILITY OF AUTONOMOUS SOLUTIONS

In late 2023, autonomous technology developer Pronto announced it was bringing its Autonomous Haulage System (AHS) to the Chilean market for use in mining and forestry applications. As Chile is a critical supplier of minerals such as lithium, the company sees use of its technology aiding their extraction which will be necessary to meet growing demand for electric vehicles.

Powered by artificial intelligence (AI) and software, AHS is designed for quick and easy adoption in various equipment types. It allows fully autonomous (Level 4) operation, meaning no human operator is required, allowing a mine to do its work even if challenged to find skilled labor.

Pronto is partnering with RAICO S.A., a mining and forestry equipment sales and rental services provider in Chile, to initially deploy its OEM-agnostic system on Bell articulated dump trucks used in mining. In the future, the companies aim to support other OEMs and applications.

"Autonomy is going to be necessary to support the world's growing demand for critical resources such as lithium and cellulose for most operations in Chile," said Cristóbal Alexandroff, Commercial Manager of RAICO, in a press release announcing the partnership with Pronto. "It is safe, reliable, environmentally friendly, and will help advance the productivity and technical capabilities of critical Chilean industries."

radation and thus increase the frequency of battery replacements.

Battery swapping, where a depleted battery is replaced with a fully charged one, is a method used in many underground mines and relatively quick to complete (5-10 minutes) which allows productivity to be maintained. Some mines are also testing use of overhead catenary lines that continuously charge the vehicle, such as a mine haul truck, as it operates which eliminates downtime for charging altogether.

These and other solutions will all need to be considered to improve charging times and the feasibility of electrification in mining.

Adoption of Autonomous Machines Rising to Overcome Labor Challenges

Development and testing of autonomous mining equipment has been going on for over a decade, with Caterpillar and Komatsu being two of the most well-known examples of OEMs working on this technology.

Labor is a key driver for the implementation of automation in mining. Mines are typically located in remote areas and known to be dusty, noisy environments. With automation, it is possible to remove human operators from these environments; instead, they can be working in a quieter, safer location remotely monitoring or controlling the equipment.

This aspect could potentially attract more people to the industry as well. Like many other off-highway and industrial applications, there is a shortage of people entering these fields. But if efforts are being made to improve the safety and comfort of a mining operation, as well as offering the opportunity to use advanced technologies, it may increase the interest of future workers.

Mining also lends itself well to autonomy, again because of the remote locations of mines, and the repetitive nature of the work. A mining vehicle typically travels the same route or makes the same movements over the course of the day, such as digging and loading mate-

Use of overhead catenary wires, also referred to as trolley systems, allow electric mining vehicles to charge continuously during operation. *S. Jensen*

rial into a vehicle. This aids the design of an autonomous system because there are known patterns which can be more easily integrated compared to the varied drive cycles of on-road vehicles.

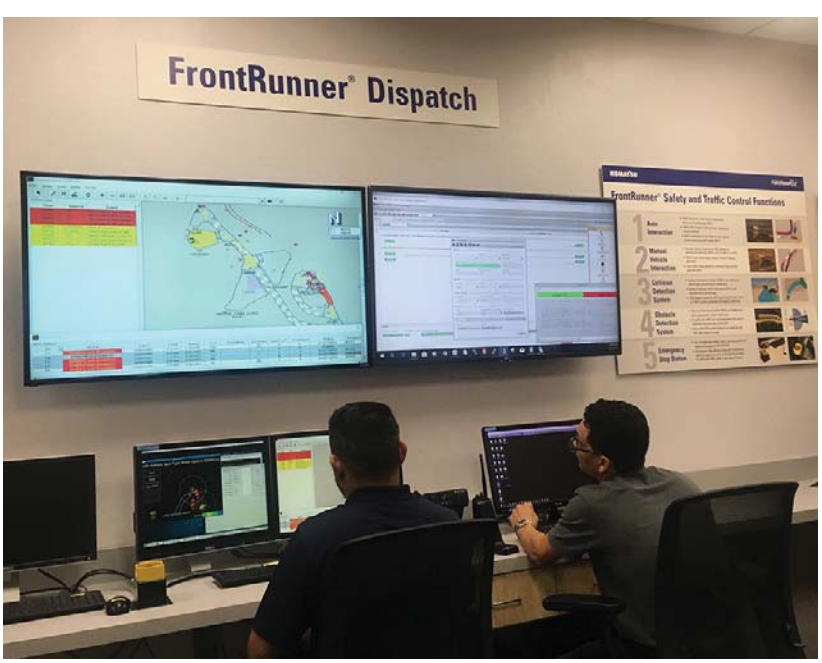
In addition, there are fewer external elements to consider as there would be with on-road applications. Machines typically work in the same environment every day and only interact with other vehicles on a mine site, reducing the number of objects on which the autonomous system needs to be trained to ensure safety.

Advancements in sensors, such as lidar and cameras, software algorithms and communication networks have helped to advance automation in mining over the years. These technological advancements have enabled better detection of various types of objects in a range of weather and environmental conditions as well as the ability to automate more mine sites and types of machines around the world.

There is of course still development work to be done, but adoption has certainly grown in line with technological capabilities. IDTechEx said use of autonomous mining equipment has been on a steady growth path since the late 2010s with an adoption boom occurring in the last 5 years. The number of autonomous mining vehicles in the global market has grown from 500 to over 1,000.

No end is likely in sight for the adoption of these vehicles as the benefits to productivity and safety continue to be realized and labor challenges persist. P&M

The remote locations of mines makes them well suited for use of automation, such as the pictured Komatsu autonomous haul truck, as there are fewer objects to interact with and cause potential safety issues. *S. Jensen*



With autonomy, workers can remotely monitor mining equipment from a safe location as demonstrated by this operational setup at Komatsu's proving grounds where it tests its autonomous machines. *S. Jensen*

Ohio Fabricators SP Series Spin-On Hydraulic Filters

Ohio Fabricators Co. has developed the SP Series hydraulic spin-on filters which are available with a range of filtration media to meet specific application requirements.
Key features of the SP Series hydraulic filters include:

- steel cased for durability
- flow rating of 22 gpm (83 lpm)
- ability to capture contaminants as small as 3 microns and
- bypass settings for pressure and suction applications.

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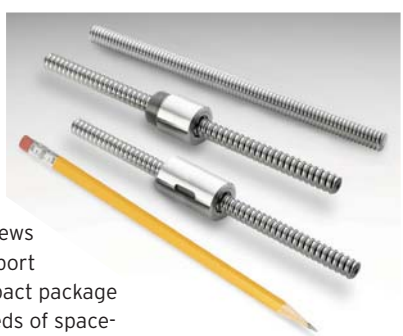
Thomson Miniature Metric Ball Screws



The Thomson Industries Inc. line of miniature ball screws are designed to support high loads in a compact package size to meet the needs of space-constrained mechatronics applications.
Key features of the miniature ball screws include:

- multi-start ball return design
- high level of repeatability
- various size options and
- durable carbon steel construction.

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[Ad Index]

Boston by Danfoss EHP530 and EHP531 Antistatic Hoses

Danfoss Power Solutions developed the Boston by Danfoss EHP530 and EHP531 antistatic hoses to provide increased safety reliability, and ease of use for oil, fuel, and gas transfer applications.
Key features of the EHP530 and EHP531 antistatic hoses include:

- protection against static buildup
- flexibility for easier installation
- pressure ratings up to 150 psi and 300 psi, respectively and
- high-tensile textile reinforcement with copper wire.

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Clippard E2S Series 10 mm Isolation Valves

Clippard has developed the electronically-controlled E2S isolation valves to provide a compact, durable option for a range of applications.
Key features of the E2S isolation valves include:

- 10 mm glass-filled nylon body for long-lasting use
- EPDM diaphragm membrane to separate actuation mechanism from flow path
- ability to dispense wide range of aggressive gases and liquids
- backpressure of less than 2 psig (0.1 bar)
- operating pressure of 0-36 psig (2.5 bar).

www.powermotiontech.com/55088066

 by Sara Jensen, Executive Editor

Automation has a Bright Future Ahead of It

Industrial automation continues to grow as a means of improving productivity as well as the quality of manufactured products. Robots of various types are enabling work to be done quickly and precisely, freeing up human workers to focus on other work.

They are also helping to keep humans from having to do some of the more dangerous or physically taxing jobs while also enabling work to be completed in those industries challenged with finding skilled workers.

Technological advancements in sensors, vision systems, motion control components and more are enabling greater adoption of robots and other automation solutions for various applications. Many of these developments were on display at Automate 2024 — an annual event which has become one of the largest focused specifically on automation technologies and robotics.

Ever increasing interest in robots and other automation technologies is bringing about a need for more education on these solutions as well as better understanding of how to choose the right option which the Association for Advancing Automation (A3) aims to provide through its event.

During Automate 2024, *Power & Motion* spoke with Clarissa Schwendeman, Director of Marketing, and Alex Shikany, Vice President of Membership & Business Intelligence, at A3 to learn more about current trends they are seeing in the automation industry and how they see it progressing in the future.

**Editor's Note: Questions and responses have been edited for clarity.*

Power & Motion (P&M): **What are some of the major trends A3 is seeing within the automation market at the moment? Are there certain technologies or applications it sees really helping drive automation uptake?**

Clarissa Schwendeman (CS): The first one that comes to mind is mobile robotics. Using mobile robots in factories really helps with dull, dirty, dangerous [jobs]…fills that labor gap. And they're [manufacturers] making them a lot easier to use.

Alex Shikany (AS): Robots are a huge one. You see more collaborative [robot] arms this year on top of mobile robots doing interesting things. Also, vision technology is very big. There are solutions with all three that we've talked about so far.

One that I saw has cameras on a collaborative robot arm that can actually help precisely locate the AMR (autonomous mobile robot) because there's very tight tolerances, so it can move and get different angles and zero in. So, we're seeing collaboration among technologies even more this year.

P&M: **Are there specific technologies A3 is hearing from members they want to learn more about, or they feel there is not enough information yet in the market about?**

CS: Industrial AI (artificial intelligence) is starting to grow; simulation technologies to learn 'What can we have in our factory? Is this the most efficient application to bring in?' That's the one I've heard most about.

AS: AI, that's got to be number one. At A3, we have our first version of our AI training that we are now doing here [at Automate] actually, and we're running it again in the fall at our AI and Smart Automation Conference. That's a huge value to the industry because we already have certification programs for vision and motion, now we can add AI to that list eventually, that's the goal, so that's a huge one.

I can't say enough about humanoids either, that's a huge topic. There's some here, [and] we just launched a new event [on the topic].

P&M: **Are there challenges with implementing or learning about what automation technologies are out there you're hearing from members, or what are their biggest struggles?**

CS: I'll speak to the big companies that are trying to start using automation, one of the challenges is where do you even begin? What is automatable? And should we automate that? Some of the advice we've heard from our members that do provide these technologies is start small. One of the other things is data. We collect so much data, what do you do with it? How do you most efficiently use it? That's part of it as well.

AS: You have to be smart about your data. I think that's where a lot of these AI software solution companies are finding a good foothold in the industry because their service allows you to make better sense of your data and deploy it in decision-making ways that are not just 'Okay, we're collecting all this now, what do we do with it?' That's definitely a challenge.

Starting small, starting smart, but starting generally — we get a lot of people here that this is their first foray into automation. We heard someone just familiarize themselves earlier in the morning with the term cobot; so we know, we hear from people that this is where they come to embark on their [automation] journey. P&M

READ THE FULL INTERVIEW at www.powermotiontech.com/55039723.

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