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September/October 2023

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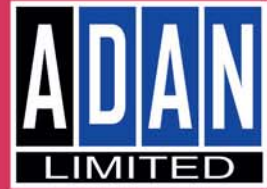
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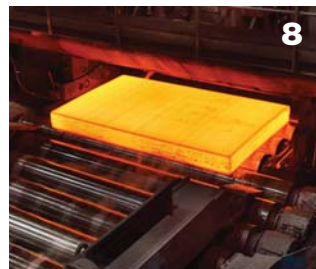
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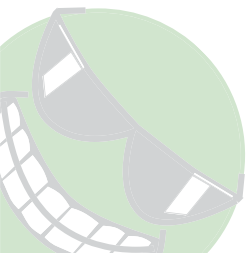
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Q&A: Improved Hydraulic System Design Enables Efficiency Gains

Leif Bruhn of Danfoss Power Solutions discusses the technology behind the Dextreme Max system for excavators and how it can improve the efficiency of hydraulic systems.

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Phased Approach Eases Upgrades to Extrusion Press Hydraulics

Employing a multi-phase approach reduces costs and downtime when upgrading extrusion press hydraulic components.

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Electric vehicles, digitalization and supply chains are among the key trends presenting new opportunities as well as challenges for the tribology and lubrication industry.

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What is the Future of IFPE?

The International Fluid Power Exhibition (IFPE) has become *the* event for fluid power manufacturers serving the mobile off-highway machinery market, particularly construction equipment. Since it began its co-location with the construction show CONEXPO-CON/AGG in 2002, it has grown to become one of the largest showcases for hydraulics and pneumatics technologies as well as other motion control and power transmission technologies.

At the National Fluid Power Association's (NFPA) 2023 Industry & Economic Outlook Conference (IEOC), president and CEO Eric Lanke said the 2023 edition of IFPE was the largest yet, with exhibitors reporting the greatest number of leads from the show.

However, NFPA recently notified members that the co-location with CONEXPO has been discontinued for the next edition set to take place in 2026. Construction at the Las Vegas Convention Center, where the show is held, space considerations and growth of the construction industry were reasons cited by the Association of Equipment Manufacturers (AEM), organizers of CONEXPO, for the decision.

Lanke informed members the fluid power industry will still have a presence at the event, though possibly in a reconfigured

manner, as will NFPA itself, due to the importance of hydraulics and pneumatics to the construction equipment market. He also told members NFPA will be assessing its options while continuing with its various other events, including those at other trade shows.

IFPE once was a standalone show which many in the industry enjoyed as both hydraulic and pneumatic technologies were well represented. While the co-location with CONEXPO has been beneficial given construction equipment is the largest customer market for fluid power, mobile hydraulics tend to be more heavily represented than other fluid power technologies, and there have been concerns over the years of it being lost among all the large equipment which takes up most of the CONEXPO space.

Though it is somewhat bittersweet to see the only IFPE I've known no longer be located with CONEXPO, I am also looking forward to seeing what NFPA has in store for the event's next chapter. **P&M**

Read an extended version of this editor's note at powermotiontech.com/21272801 and let us know your thoughts on what the future of IFPE could, or should, look like.



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Epiroc and SSAB are researching the potential of using fossil-free steel to 3D print spare parts and machine components.

Epiroc

Manufacturers Researching More Sustainable Component Production Process

Epiroc and SSAB are researching the use of fossil-free steel and 3D printing to manufacture hydraulic and other components for mining equipment.

by Sara Jensen

Mining equipment manufacturer Epiroc is collaborating with steel manufacturer SSAB to research the potential of using fossil-free steel for the production of spare parts and components using additive manufacturing (aka 3D printing). The goal is to make the manufacture of components more sustainable while also offering potential design and performance improvements.

In 2016, SSAB launched its initiative for the creation of fossil-free steel. After several years of development, in 2021 the company's joint venture for this initiative, HYBRIT, produced what was considered to be the world's first fossil-free steel. Instead of using coal and coke in the steel production process, fossil-free hydrogen is utilized, as well as fossil-free energy in all aspects of the value chain, which eliminates carbon dioxide (CO₂) emissions—and thus creating a more sustainable manufacturing process for steel.

The use of additive manufacturing (AM) itself can provide sustainability benefits as well as it can reduce the amount of material needed to produce a part. Often there is less machining required with parts made using AM, reducing energy consumption and again benefitting sustainability efforts.

AM Improves Hydraulic Component Design

The companies have begun their research with a hydraulic block typically used on Epiroc's mining rock drills. To start, they 3D printed a prototype of the hydraulic block using conventional steel powder.

According to Epiroc, traditional manufacturing of the hydraulic block uses milling and drilling which leads



to the block needing to be plugged and sealed after production to prevent leaks. However, by producing the part with AM, six potential leak points were completely eliminated. This helps to reduce the amount of extra work that would otherwise be necessary to add the plugs and seals as well as minimizes hydraulic oil leaks which could harm the environment.

Using AM to produce the hydraulic block also offers the potential to improve the flow of hydraulic oil through the block because there are no longer any sharp edges which could impede flow as there often are with traditional manufacturing practices.

Another benefit the companies found AM offers is the ability to reduce the weight of the hydraulic block. Epiroc said in its press release announcing the collaboration with SSAB that a steel block weighing approximately 50 kg is typically used when traditional manufacturing processes are employed. But the optimized component design for AM required only a 7.5 kg block of steel, reducing the amount of material required by 85%.

The end product created using AM weighed just 6.6 kg, a weight reduction of 55% said Epiroc. Hydraulic blocks produced using traditional manufacturing processes typically weigh 15 kg.

This weight reduction benefits not only the manufacturing process but has the potential to also benefit the machine in which the hydraulic block will be utilized. Epiroc explained in its press release that rock drills are positioned far out on the feed of the drill rig and therefore weight can have a substantial impact on the machine. But use of new technologies such

as 3D printing could enable the creation of stronger components without negatively impacting the balance of the machine, the company said. It also noted reducing weight on the machine's feed could help to improve the lifecycle of other components as it would lead to less stress and load being placed on them.

Now that a successful prototype has been created using AM, the companies will next evaluate the potential of using fossil-free steel powder.

"Production and shipping of spare parts are interesting areas for us to explore going forward. There is a lot of potential in many ways, we can decrease lead times, increase availability, cut cost on transportation and most important of all—reduce our environmental footprint," said Anders Flodman, engineering manager at Epiroc, in the company's press release.

Fossil-Free Steel Will Aid Emissions Reduction Goals

Since its fossil-free steel, known as SSAB Fossil-free, became available, SSAB has worked with Epiroc and other heavy equipment OEMs such as Volvo Construction Equipment to incorporate the steel into their machine designs.

In April 2022, Epiroc announced it would work with SSAB to use the fossil-free steel for a prototype of its battery-electric Minetruck MT42, and increase use of the steel over time. Doing so is in line with the OEM's sustainability goals.

"Sustainability is integrated in everything we do, and we are committed to halving our CO₂ emissions by 2030. This exciting partnership with SSAB will support us and our customers on the journey to reach our very ambitious climate goals," said Helena Hedblom, Epiroc's president and CEO, in the company's press release announcing its first use of the SSAB steel. "It is clear that our innovation agenda goes hand-in-hand with our customers' sustainability agenda." **P&M**

Read the full article at [powermotiontech.com/21268688](https://www.powermotiontech.com/21268688).

Winners Announced for 2023 IDEA Awards

by Sara Jensen

The votes have been tabulated for the annual IDEA Awards honoring new product innovations, with winners and honorees crowned in 10 categories. Design and manufacturing professionals from around the world were eligible to cast their vote.

In addition to the winners and honorees in each category, one BIG IDEA Winner was selected. The SiTime SIT7910 temperature-compensated oscillator (TCXO) received the highest number of votes in all categories which enabled it to receive the BIG IDEA designation.

"We know product innovation is important to our readers and to the larger supplier community. It is only through the continued innovations of technology, components and systems can manufacturing meet the challenges of today and tomorrow," said Bob Vavra, senior content director for *Power & Motion* and *Machine Design*. "This year's winners, chosen by our readers, are a great example of how that innovation becomes products that advance the goals of manufacturers everywhere—to be safer, smarter and better-connected manufacturing enterprises."

The IDEA Awards are presented by *Power & Motion* and other publications in Endeavor Business Media's Design & Engineering Group.



The 2023 IDEA Awards winners are:

BIG IDEA Winner

SiTime SiT7910 temperature-compensated oscillator (TCXO)

Additive & Materials Management

Protolabs Instant Design for Additive Manufacturability (DfAM) Analysis

Automation & Controls

Red Lion N-Tron Series NT5000 Gigabit Managed Layer 2 Ethernet switches

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Assessing Future Design Needs for Hydraulics and Pneumatics

The 2023 NFPA Technology Roadmap outlines the key areas in which the fluid power industry should focus future development initiatives.

by Sara Jensen

Continued technological advancements in hydraulics and pneumatics will be driven by a range of industry trends and customer requirements. To help guide future designs, the National Fluid Power Association (NFPA) has published its 2023 Technology Roadmap, a document outlining target areas in which the fluid power industry should consider focusing its development efforts.

“The technology roadmap is a document that describes the industry-wide consensus regarding the precompetitive research and development (R&D) needs associated with improving the design, manufacture and function of fluid power components and systems,” said Eric Lanke, president and CEO of NFPA, during a presentation announcing publication of the roadmap at the association’s 2023 Industry & Economic Outlook Conference (IEOC). “It’s an R&D agenda of what we need to do to improve our fluid power products, so that they can play a larger role in the technology strategies of our many different customer groups.

“It’s used widely across our supply chain by our academic partners to guide their research efforts, by our own members to make decisions about product development choices or partnerships that they want to enter into; increasingly, it’s actually being used by academic, government and other organizations that are funding research and want to pursue projects that are of importance to our industry,” he said.

As described in the Technology Roadmap, it is comprised of five key elements:

- **Customer Drivers**—the top-level performance objectives of fluid power customers, the OEMs or machine builders that manufacture machines that often incorporate fluid power systems. Customer Drivers help these machine builders serve the needs of their own customers and are not necessarily connected to their use of fluid power.
- **Customer Strategies**—the machine-level objectives and technologies that the machine builders have set or are using to help them achieve the top-level performance objectives described by the Customer Drivers. These Customer Strategies are not necessarily connected to their use of fluid power.
- **Capability Improvements**—the ways in which fluid power systems must improve if they are to participate or increase their participation in the technology trends described by the Customer Strategies.
- **Research Areas**—the broad areas of pre-competitive investigation that could assist in bringing about the Capability Improvements.
- **Research Targets**—the objectives that quantify or otherwise describe successful strategies for pursuing the Research Areas.

What Customers Want from Fluid Power

To determine the areas in which fluid power manufacturers should focus their future design efforts, it is necessary to first understand what performance aspects are important to their

customers. “You don’t innovate for the sake of innovation; you innovate to solve problems. Starting with the customer drivers and then working from there really gives a lot of credibility to the roadmap,” said Steve Meislahn, managing director, Sun Hydraulics and vice chair of the NFPA Roadmap Committee, during the presentation on publishing of the roadmap document at the 2023 IEOC.

NFPA surveyed members and others across the fluid power supply chain to help determine key technology needs for the top 20 largest customer markets. Construction and agricultural machinery, material handling, automotive and trucking, various manufacturing segments and more are among the top fluid power customer markets noted by NFPA in the technology roadmap.

“These are the 20 markets that we really paid most attention to as we went through the strategy...so, when we talk about customers and their needs, its customers that fit into one of these 20 major markets,” said Lanke.

In determining key fluid power customer needs for the 2023 roadmap, NFPA first asked survey respondents to assess those laid out in the 2021 edition—such as increased availability and uptime, increased performance and on-time delivery—as well as what new drivers may have emerged since the publishing of that document. For the latter, autonomous operation, machine communication and ease of serviceability were among the top responses.

The NFPA Roadmap Committee used these survey responses to narrow down the performance aspects customers desire from fluid power components. It decided the best way to do so was distinguishing between Customer Drivers and Customer Strategies. “The drivers are what they want to achieve, and the strategies are how they’re going about achieving those drivers,” explained Lanke.

The top four Customer Drivers outlined in the 2023 roadmap are:

- Increased availability and uptime
- Increased productivity and performance

- Lower total cost of ownership
- Compliance with regulations.

Based on those drivers, the following eight Customer Strategies were determined:

- **Autonomy**—Either semi- or fully-autonomous functions and/or operations.
- **Compactness**—Increasing power density and/or reducing weight and/or size.
- **Connectivity**—Expanding the use of data, such as intelligence for cloud-based condition monitoring, integration with site management systems, and/or communicating machine status for other value-added purposes.
- **Electrification**—Decarbonizing prime movers through a variety of strategies. Currently connected to regulations; likely connected to productivity in the future.
- **Energy Efficiency**—Increasing it; and including strategies to improve battery life and/or charging and to use less energy and/or reduce emissions.
- **Maintenance**—Making it easier; and including strategies to ease the serviceability of the machine and to increase the availability of repair and replacement parts.
- **Materials**—Use of conflict and/or environmentally friendly materials in strategic ways to better comply with regulations.
- **Noise**—Reducing perceived noise levels and/or improving noise pulsation. Connected to productivity when operators are more comfortable and able to work in “new” areas.

Meislahn said that connectivity and electrification, and the addition of sensors to get data are the top requests his company is hearing from customers. Autonomy is the objective many are trying to achieve, and connectivity and electrification are among the foundational steps for achieving that goal, he said.

From a pneumatics perspective, Scott Meldeau, vice president, Norgren—a company which also took part in the Roadmap Committee—said during the IEOC presentation that connectivity and electrification were also growing areas of interest. There are also some upcoming regulations

which could have a direct impact on pneumatics manufacturers and their customers.

How Well is Fluid Power Meeting Customer Needs?

While reviewing survey responses for the key customer drivers, the Roadmap Committee found there was not much variation between those of most importance to the top hydraulics and pneumatics customer markets. The most important drivers—“Increased availability and uptime” and “Increased productivity and



Advancements in hydraulic component and system designs will help to ensure they remain a vital part of various machine and vehicle designs.

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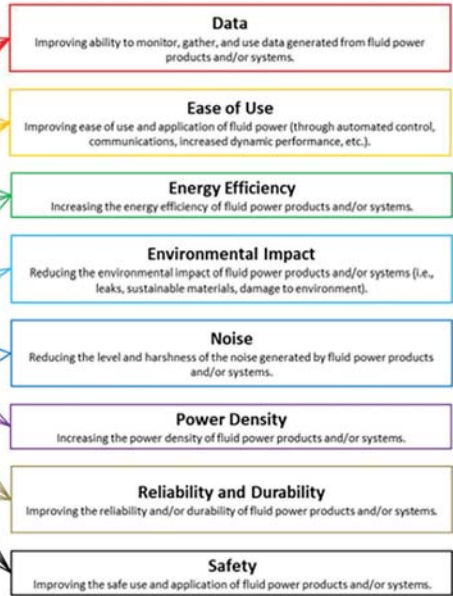
CUSTOMER STRATEGIES

Machine-Level Objectives and Technologies That Help Achieve Performance Objectives



CAPABILITY IMPROVEMENTS

Improvements to Fluid Power Systems to Increase Their Use in Customer Strategies



← Connections flow this way
Capability Improvement supports Customer Strategy

Various Capability Improvements for fluid power components and systems can help achieve customers' desired performance targets. Lines between the Capability Improvements on the right are connected to those Customer Strategies they best correspond with on the left.

NATIONAL FLUID POWER ASSOCIATION

performance”—were noted as such by both customer segments, demonstrating the broad appeal of these performance targets.

However, the customer driver “Increased energy efficiency” ranked slightly higher for hydraulic customer markets and for pneumatics customers it was “Easier and more predictable maintenance,” indicating potential areas in which fluid power manufacturers should focus future developments.

After determining the key customer performance requirements, NFPA next surveyed the fluid power supply chain to determine the industry’s ability to meet them as outlined by the Customer Strategies. Individual surveys were sent related to hydraulics and pneumatics to best assess how each technology is meeting OEM and machine builders’ needs.

From the responses, it was determined the hydraulics sector does well at meeting customers’ Compactness and Materials requirements, but the largest improvements could yet be made in the areas of Connectivity and Electrification.

Maintenance was the Customer Strategy for which pneumatics currently appears to be well aligned based on the survey results. Electrification and Compactness were the top areas of potential improvement.

Based on these surveys and customer performance objectives, the Roadmap Committee next outlined the Capability Improvements that would be needed for fluid power systems to meet the Customer Strategies. Survey participants were asked to assess the Capability Improvements laid out in the 2021 edition of the roadmap as well as offer new suggestions.

From the responses to each of those questions, the committee determined the eight Capability Improvements which could be made to fluid power systems:

- **Data**—Improving the ability to monitor, gather and use data generated from fluid power products and/or systems.
- **Ease of Use**—Improving ease of use and application of fluid power (through automated control, communications, increased dynamic performance, etc.).
- **Energy Efficiency**—Increasing the energy efficiency of fluid power products and/or systems.
- **Environmental Impact**—Reducing the environmental impact of fluid power products and/or systems (i.e., leaks, sustainable materials, damage to environment).
- **Noise**—Reducing the level and harshness of the noise generated by fluid power products and/or systems.
- **Power Density**—Increasing the power density of fluid power products and/or systems.
- **Reliability and Durability**—Improving the reliability and/or durability of fluid power products and/or systems.
- **Safety**—Improving the safe use and application of fluid power products and/or systems.

Lanke said this is the first time he can recall the need to increase safety making it into the roadmap, demonstrating the growing importance of “[ensuring] fluid power systems are safe and easy to use within the different customer strategies.”

He went on to say that these Capability Improvements can provide a helpful guide for fluid power companies who want to help customers with the strategies they are pursuing as well as determine ways to develop or improve hydraulic and pneumatic products.

From Meislahn’s perspective, ease of use is likely the most critical Capability Improvement for the industry. He said there are a lot of connectivity and data technologies out there, like

Development areas for hydraulics and pneumatics laid out in the Technology Roadmap can help a range of customer markets including construction equipment.

CANbus, for which more fundamental knowledge is needed to aid with ease of use. “A lot of these technologies exist but they’re not really intuitive or easy to put together,” he said. As such, he sees it as an area of improvement which could help the fluid power industry keep up with competing technologies.

Meldeau sees data as a key area of focus, especially in terms of making sense of the data which is collected and interpreting it in a valuable way. The connectivity side is also of importance for helping to understand how a whole system is behaving.

Future Hydraulic and Pneumatic Design Initiatives

To help fluid power manufacturers develop their products in a way that will meet the Capability Improvements, the roadmap

includes research areas and targets for each which could help manufacturers achieve those improvements.

Similar to the other elements of the Technology Roadmap, members of the fluid power supply chain were asked what Research Areas outlined in the 2021 roadmap could aid with the 2023 Capability Improvements and what new areas of research may be needed. Based on survey responses, the following Research Areas were determined for the 2023 Technology Roadmap:

- Components—Develop new fluid power components.
- Control—Improve the controllability of fluid power systems.
- Data Analytics—Improve use of data analytics in fluid power systems.
- Fluids—Optimize the use of fluids and lubrication in fluid power systems.
- Manufacturing—Develop/apply new manufacturing technologies for fluid power components and systems.
- Materials—Develop/apply new materials in fluid power components and systems.
- Seals—Optimize the use of seal technologies in fluid power systems.
- Sensors—Advance sensor technologies used in fluid power systems.

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Increased productivity and performance
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Lower total cost of ownership
Includes capital and/or operating costs.

Compliance with regulations
Such as those pertaining to environmental, safety, or other concerns.

CUSTOMER STRATEGIES

Machine-Level Objectives and Technologies That Help Achieve
Performance Objectives

Autonomy
Either semi- or fully-autonomous functions and/or operations.

Compactness
Increasing power density and/or reducing weight and/or size.

Connectivity
Expanding the use of data, such as intelligence for cloud-based condition monitoring, integration with site management systems, and/or communicating machine status for other value-added purposes.

Electrification
Decarbonizing prime movers through a variety of strategies. Currently connected to regulations; likely connected to productivity in the future.

Energy Efficiency
Increasing it; and including strategies to improve battery life and/or charging and to use less energy and/or reduce emissions.

Maintenance
Making it easier; and including strategies to ease the serviceability of the machine and to increase the availability of repair and replacement parts.

Materials
Use of conflict and/or environmentally friendly materials in strategic ways to better comply with regulations.

Noise
Reducing perceived noise levels and/or improving noise pulsation. Connected to productivity when operators are more comfortable and able to work in "new" areas.

← Connections flow this way
Customer Strategy supports Customer Driver

The NFPA Roadmap Committee determined there were eight key Customer Strategies of focus for the fluid power industry which can be tied to the top Customer Drivers, as demonstrated by the lines going between the boxes. NATIONAL FLUID POWER ASSOCIATION

- System Architecture—Explore novel fluid power system architectures.

From here, a list of Research—objectives that will aid pursuit of the Research Areas—were outlined by the Roadmap Committee for each of the Capability Improvements. To do so, the committee created working groups for each Capability Improvement which created a prioritized list of Research Areas and Targets for their assigned improvement.

As an example, for the Capability Improvement of Data it was determined by the committee Data Analytics and Sensors were the top Research Areas on which to focus. From there, the top Research Targets for each are outlined in the roadmap:

Data Analytics

- Improve data processing capabilities through the use of edge computing (on-board sensing and processing) and/or through the use of cloud computing.
- Data Analysis: Improve data analysis capabilities through the use of artificial intelligence and/or machine learning.
- Data Utilization: Apply improved data gathering, processing, and analysis capabilities to specific machine or system outcomes, including increased efficiency, automated functions and/or operation, and end-of-life prognostics and preventative maintenance.

Sensors

- Wireless Sensors: Improve the capabilities, reliability, and availability of wireless sensors for use in fluid power systems. Pursue strategies to improve their connectivity to data-generating devices, to embed them in components and systems and lowering their maintenance requirements

(no need to replace batteries or recalibrate, self-diagnosing, failure-proof), and to lower their cost without reducing their effectiveness.

- Sensor Materials: Develop and apply sensor materials that are non-aluminum and non-sparking.

LANKE said the Roadmap Committee was then tasked with prioritizing the Research Targets to those which would “likely have the largest opportunity to move the needle in making progress on fluid power capability development and system applications for some of the Customer Strategies.”

The committee narrowed the list down to 12 Research Targets which coincide with each of the Research Areas:

- Prediction Tools—Analyze impact of operational realities on components and develop modeling and prediction tools for their lifecycle and potential failure.
- Power Density—Develop more power dense components; ensure their safe use and application.
- On-Demand Power—Improve and develop on-demand power capabilities.
- Data Utilization—Apply improved data gathering, processing and analysis capabilities to specific machine or system outcomes.
- Environmentally Friendly—Develop longer-lasting, biodegradable, environmentally-friendly fluids that reduce leakage and improve efficiency.
- Additive—Develop cost-competitive additive materials, develop improved design tools for, and apply additive manufacturing to produce high-pressure capable components.

- Coatings—Develop coatings that reduce friction and heat.
- Higher Pressure—Test and record the max pressure ratings for different materials used in components; improve ability of components to handle higher pressures.
- Seal Materials—Develop new and sustainable seal and wear-ring technologies that can resist wear, reduce friction and eliminate external leakage.
- Prediction Tools—Improve ability to measure and predict seal wear and life.

How the NFPA Technology Roadmap Comes Together

The National Fluid Power Association (NFPA) updates its Technology Roadmap every other year to ensure the fluid power industry is staying on top of the most current technology needs. It gains input from various stakeholders within the hydraulics and pneumatics supply chain, including member companies, partner associations and more.

A Roadmap Committee helps to oversee the process of collecting information which is gained via surveys over the course of several months. The committee works to review the survey results and compile them into a cohesive document for the fluid power industry.

- Wireless Sensors—Improve the capabilities, reliability and availability of wireless sensors for use in fluid power systems.
- Distributed Systems—Develop more efficient, distributed system architectures.

Of the Research Areas and Targets, Meislahn said data analytics is the one which jumps out to him as a high priority because of all the sensor integration and data collection taking place. Determining how to use the data and provide value to customers will be key as well. He also noted the importance of control and power-on-demand capabilities as battery-electric vehicles become more commonplace in various industries.

Meldeau agreed that data analytics and making sense of the data collected are key areas on which the industry should focus research efforts. He noted additive manufacturing is an area of interest as well, looking at use of different metals and the other potential opportunities.

Overall, the Technology Roadmap outlines a wide range of areas in which the fluid power industry can focus its future developments. But as Lanke said, it also demonstrates the fact there is a lot of opportunity for the industry as well as discussions and partnerships between the many companies in the broader hydraulics and pneumatics supply chain. **P&M**



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A New Approach to Hydraulic Reservoir Designs

The Cyclone Hydraulic Reservoir reduces space claim and hydraulic oil use, benefiting machine designs and customer costs.

by Sara Jensen

Hdraulic reservoirs play an important role in hydraulic systems as they store fluid as well as aid with heat dissipation and fluid conditioning. However, they are often oversized which can cause design challenges for heavy equipment manufacturers.

Price Engineering's Cyclone Hydraulic Reservoir looks to overcome this by offering a more compact option without compromising fluid flow or other desired performance aspects.

"Historically, the hydraulic reservoir is two to three times the size of the gpm (gallons per minute) of the [hydraulic system's] pump," said Tom Price, president, Price Engineering, a SunSource Company, in an interview with *Power & Motion*. "If your pump was 20 gpm, you had a 40 or 60 gal. reservoir."

By instead using a smaller option like Cyclone, OEMs can overcome these space constraint challenges and achieve additional benefits as well.

Advantages of Using Smaller Hydraulic Reservoirs

According to Price, the Cyclone Reservoir is physically about 10 times smaller than the traditional 20-gal. versions mounted on many machines. Not only does this reduce the amount of space required for the reservoir but also overall machine weight.

Reducing machine weight can lead to efficiency improvements, another aspect which is becoming increasingly important to heavy equipment manufacturers as it can help to reduce fuel costs for customers as well as aid with efforts to lower emissions. This will also benefit development of hybrid- and full-electric machines where weight and efficiency are key design criteria.

With the reservoir's smaller size also comes the ability to use less oil. A 20 gpm Cyclone requires only 1 gal. of oil said Price, providing further weight savings as well as reduced costs for end-use customers. Hydraulic oil is not getting any cheaper, he said. "High quality and biodegradable oils are getting quite expensive. So, to be able to save [money] is important."

OEMs can benefit from use of the reservoir as well. Besides aiding their machine designs, Cyclone's smaller size reduces the amount of inventory space required at a manufacturing facility. The smaller size and weight of the hydraulic reservoir can also help to lower shipping costs.

Cyclone Prevents Air and Oil from Mixing

In addition to its smaller size, the technology used within the Cyclone Hydraulic Reservoir can also benefit machine owners.



Etnyre chose to integrate the Cyclone Hydraulic Reservoir in one of its tow-behind machines, shown here at CONEXPO 2023, to help simplify the design and reduce weight.

ANDREW DLUGOKECKI

This sizing convention has led to use of larger reservoirs over the years and increased space claim in machines. Price said real estate in mobile equipment is becoming increasingly important to OEMs as they look to put more value-add technologies onto their machines as well as components for meeting emissions regulations.

Unlike a typical reservoir, Cyclone features a cylindrical shape and uses centrifugal force to remove air from hydraulic fluids. Doing so helps to ensure optimized system and overall machine performance.

Price explained that air is typically dissolved in these fluids but once oil starts pumping through the hydraulic system and pressure is created, air bubbles can form. As hydraulic oil flows through the system, it flows through corners and orifices which could cause the formation of vacuums, leading air to be pulled out of the oil and bubbles to form—leading to potential performance issues.

“I always like to say a clear jar of oil looks like a good lager beer,” he said. “However, when you get an oil that has been emulsified over and over it comes back looking like milk.”

It is important to avoid air and oil mixing to a point where the hydraulic oil looks like milk. This means oxidation has occurred which can cause compressibility problems, cavitation and other issues that negatively impact the performance of the hydraulic system and the machine.

This is an issue all heavy equipment manufacturers recognize occurs and want to solve said Price. However, the traditional solution has been to use larger reservoirs which allow the air bubbles to float to the top of the hydraulic reservoir tank.

Cyclone, on the other hand, uses a spinning technique to create centrifugal forces which push the heavier oil to the outside wall of the reservoir for use in the hydraulic system. The lighter air bubbles are kept at the center by a cyclone effect and pushed to the air space above the hydraulic fluid. The air is released out of the reservoir into the atmosphere through a

filler/breather cap, ensuring the fluid continues to look like a lager beer and the hydraulic system performs as desired.

Construction Equipment Manufacturer Benefits from Smaller Hydraulic Reservoir

The Cyclone Reservoir can be used in a variety of mobile and stationary applications. Etnyre, a manufacturer of asphalt road construction equipment, is one of the many OEMs which has seen the benefits provided by the device.

A small tow-behind machine was the first onto which Etnyre integrated the reservoir. “We needed to find a way to simplify our design and reduce weight of the machine,” said Randy Tattershall, director of RES Sales, Etnyre, in an interview with *Power & Motion*. “Space constraints are always a challenge, especially on smaller machines.”

After conducting research on the Cyclone technology, Tattershall said the company did some prototyping with it and was impressed by the results. “We put it on a machine out in the field and had no issues with it,” he said. “Now all our machines of that type are using the reservoir.”

Tattershall said use of the hydraulic reservoir helped to reduce space claim as well as oil used in the machine. The latter helps with maintenance as there is less oil that needs to be disposed of, he said. “It is very environmentally friendly in that regard. That’s a big movement for our company to try and be as environmentally friendly in our designs and applications as possible.”

When integrating the Cyclone Reservoir into its machine, Tattershall said Etnyre found it needed to add a small heat

exchanger as well to help with temperature displacement as there was no longer the volume of oil in the machine to aid with this as there was with previous reservoirs. “But it was a modest expense and not really an issue as we moved forward with the design,” he explained.

One aspect he said should be top of mind when integrating the Cyclone Hydraulic Reservoir is ensuring it is sized appropriately for the flow required of the application. Designers must understand the hydraulic flow needs of their machine and be careful to choose the right size reservoir to meet performance requirements. Working together with the Price Engineering team can help with this, he said.



Because of its compact design, the Cyclone Reservoir benefits space-constrained machine designs by taking up less real estate than conventional options. PRICE ENGINEERING

Tattershall said it is important for machine designers like Etnyre to embrace newer technologies, especially those which can provide some environmental benefits like Cyclone does with its reduced oil use. While machine performance may not be improved simply because the hydraulic reservoir was changed,

the space savings it enables offers that possibility. "It gives us an opportunity to have more space and maybe do some other machine enhancements because that footprint and weight are not tied up by a large reservoir," he said.

Etnyre is currently using the Cyclone Reservoir on a few of its smaller machine



Integration of the Cyclone Reservoir on an Etnyre tow-behind machine reduces space claim and the amount of oil that would need to be disposed of during maintenance.

ANDREW DLUGOCECKI

applications and is "very happy with the results," said Tattershall. There has been a need to educate customers on the benefits a smaller reservoir can provide, particularly in regard to the cost savings which can be achieved through reduced oil use, but so far it has been positively received he said. **P&M**

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Ongoing Hydraulic Reservoir Development

Since first acquiring the Cyclone Hydraulic Reservoir technology from Eaton in 2005, Price Engineering has continued to develop the technology to meet evolving customer requirements. As such, it is now available in multiple configurations and flow sizes.

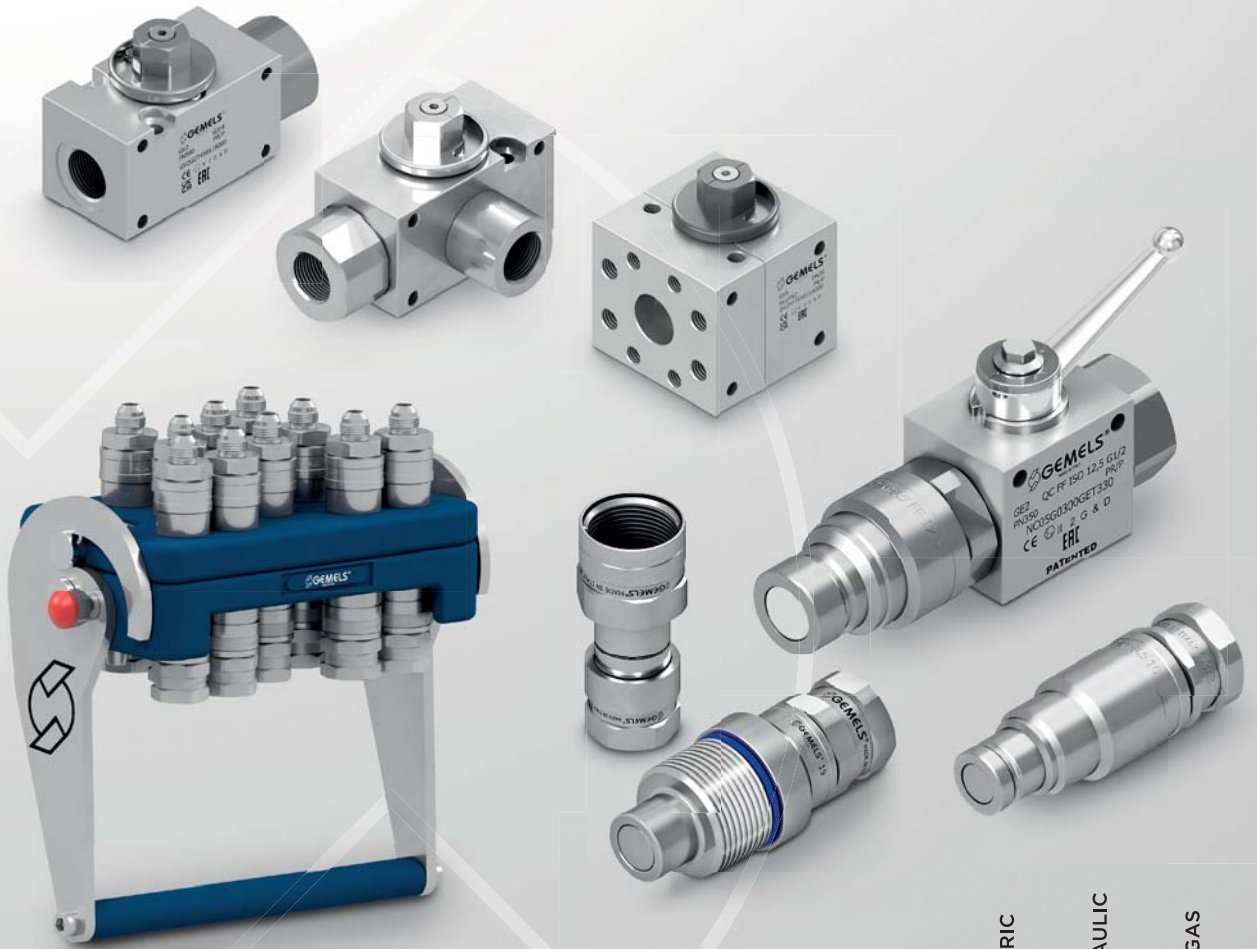
Versions of the hydraulic reservoir with a nylon housing are available with flow rates of 8, 13 and 20 gpm while those with a steel housing are available in 20, 40, 60, 80 and 100 gpm. Custom versions are also available.

Tom Price, President of Price Engineering, said the company initially thought the standard volume hydraulic reservoir tanks it developed would not work well with large hydraulic cylinder circuits. But after some research, it found extended volumes could be achieved with its standard tanks. As such, the 20, 40, 60 and 80 gpm reservoirs are available in taller versions to provide more hydraulic oil for more cylinder displacement volume he said.

The company plans to continue evaluating and developing the Cyclone Reservoir design to ensure it meets varied customer and application requirements.



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Use of artificial intelligence and machine learning are helping manufacturers improve their production processes. FLEX

How AI and ML are Revolutionizing Electronics Manufacturing

Use of artificial intelligence and machine learning are helping to improve the production process for electronics and other manufacturers.

by **Murad Kurwa, Rahul Katkar**

Artificial intelligence (AI) has been hotly debated in headlines and across industries. Is it safe? Good for business? The way of the future? While the debate rages on, one thing has become abundantly clear: AI is finding its place on the factory floor and will only continue to scale.

The reason? The rise of the fourth industrial revolution (Industry 4.0) has brought about significant opportunities for manufacturers to optimize processes, costs and streamline throughput. And manufacturers are tapping into the power of advanced technologies like AI and machine learning (ML) to reap these benefits.

The applications of AI and ML in electronics manufacturing in particular are numerous, from advanced predictions and quality assurance to waste reduction and more. There are several challenges AI and ML can help solve on the factory floor.

Challenges Faced by Electronics Manufacturers

As electronic devices and systems have become ubiquitous, and their production increasingly complex, manufacturers face several challenges, including:

- **Inefficient Maintenance and Downtime:** Manufacturing equipment requires frequent maintenance. Inefficient monitoring and updates can result in costly repairs and replacements. Additionally, inadequate visibility into operations makes it difficult to detect abnormalities and predict required maintenance, which can lead to unplanned downtime.
- **Ensuring World Class Quality:** Manufacturers must detect and address product defects and quality issues early in the product lifecycle without the lengthy process of human inspection to meet volume demands and avoid scrap.

- **High Operational Costs:** For products requiring vision inspection, a person cannot catch every imperfection in every product that goes through the production line. Unplanned interruptions from quality issues can cost significant amounts of money, cause delays in output and be disruptive to customer relationships.

Benefits of AI and ML in Electronics Manufacturing

The good news? AI and ML can play a role in tackling the challenges faced by electronics manufacturers. These advanced manufacturing technologies have quickly become essential tools for optimizing the manufacturing process. Some of the benefits of using these technologies include:

- **Predictive Maintenance:** Intelligent systems can be used to predict, detect and alert manufacturers to potential failures in their factory equipment. Predictive maintenance helps reduce downtime, improve reliability and increase efficiency.



- **Quality Control:** By using AI and ML algorithms, manufacturers can identify defects and quality issues in real time. This allows them to adjust the manufacturing process to reduce waste and increase quality assurance across production volumes.
- **Process Optimization:** By collecting and analyzing data from various sources and parts of the process, like production lines, sensors and equipment, manufacturers can optimize the manufacturing process faster and more efficiently.

How AI and ML are Being Used on the Factory Floor

To understand the full potential of using AI and ML, it can be beneficial to see how they are being employed in a real-world manufacturing operation.

Flex, a global electronics manufacturer, produces thousands of printed circuit boards (PCBs). They are crucial components in all electronic devices but have often remained reliant on human inspection for quality control.

Products that require visual inspection are traditionally inspected by human workers as they travel through the manufacturing line. Yet, as product demands and timeline

speeds have increased, it becomes more difficult for the human eye to detect anomalies. To combat this challenge, Flex implemented an AI/ML-based defect detection system using deep neural networks to detect defects that are difficult to see with conventional vision systems or by human inspectors.

Flex's new tool not only streamlined inspection processes, resulting in greater efficiency performance of over 30% and improved product yield by 97%, but also helped the company reduce scrap by identifying issues before sending a part to another step in the production line. It also helped optimize factory floor space, making room for other lines and solutions by eliminating legacy inspection stations.

Perhaps the most significant impact was on the inspection staff, who were given training in managing these innovative technologies. This increased morale and provided employees with advanced career opportunities, rather than focusing on the tedious process of inspecting products.

Lessons Learned from AI and ML Implementation

AI and ML technologies hold sheer unlimited promise and will continue to fundamentally change the manufacturing industry. But there is still much to learn about these powerful tools.

In production, Flex encountered countless lessons, such as:

- **Data readiness:** AI/ML models use algorithms to recognize patterns in data and learn from them, so the quality of an AI/ML model is only as good as the training data. This requires due diligence in making sure that the datasets conform to your requirements and that you're applying the right analytical methods against that data.
- **Ambiguous ROI:** Quantifying the return on investment from AI and ML solutions is not easy. Organizations need to identify the right use cases for the business, find relevant data, process it and then develop, fine-tune, and eventually deploy models—all of which are vital and take time.
- **Real-Time Decision Making:** Time-crucial applications are related to safety issues, monitoring quality and more. But due to a common lack of system interoperability, the continuous cycle of "closed loop" updates and improvements can be a challenge. To overcome this challenge, companies need to implement digitization.

Optimizing Electronics Manufacturing with AI and ML

Manufacturers today are successfully leveraging AI and ML in their manufacturing processes, such as Flex's AI/ML-powered vision inspection tool implementation.

While hurdles remain, advanced technologies like AI and ML are at the forefront of Industry 4.0 and have the power to transform production and operations on every level. **P&M**

This article was written and contributed by Murad Kurwa and Rahul Katkar of Flex.

8 Advantages to Using Air Bearings

Air bearings provide a maintenance-free, highly accurate alternative to mechanical bearings which benefit use in precision motion and automation applications.

by Stefan Vorndran

While mechanical bearing guidance is suitable for most motion applications, it has many drawbacks. In applications where lifetime, minimal vibrations, optimal precision, repeatability or geometric performance are essential, air bearings can provide superior performance and deserve a closer look.

Air bearings and air bearing motion stages utilize a cushion of air to eliminate mechanical contact, thereby effectively mitigating common problems associated with traditional bearings such as friction, wear, vibration, hysteresis effects and particle generation.

These factors serve as key indicators that air bearing stages may be the ideal choice for high precision, 24/7 test automation and metrology applications.

How Air Bearings Achieve Exceptional Precision

Air bearing surfaces are usually hard coated and meticulously ground to achieve exceptional tolerances. High bearing stiffness is achieved by frictionless magnetic or vacuum preloading. The surface averaging effect helps to provide significantly better geometric performance, such as straightness and flatness because the large area of the bearing together with the precision ground surfaces can deal much better with small imperfections than ball bearings or roller bearings (see Figure 2).

The effect can be compared to the difference between a hovercraft and a conventional truck riding over a pot-hole-covered highway. That averaging effect is also comparable to the smoothness of a magnetic levitation train versus a conventional train running on steel wheels.

With the absence of wear, and no need for lubrication and maintenance, air bearings offer

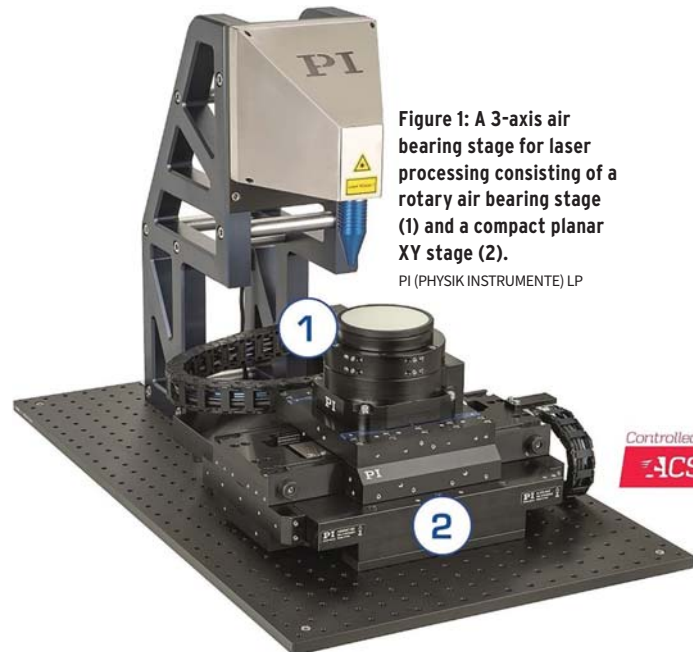


Figure 1: A 3-axis air bearing stage for laser processing consisting of a rotary air bearing stage (1) and a compact planar XY stage (2).

PI (PHYSIK INSTRUMENTE) LP

considerable benefits in high-speed motion applications and precise positioning, particularly in high throughput 24/7 automation scenarios that are demanding high uptime and reliability.

Why Air Bearings Benefit Precision Motion and Positioning Applications

There are eight key advantages air bearings can provide over mechanical bearings when used in applications requiring precision motion and positioning.

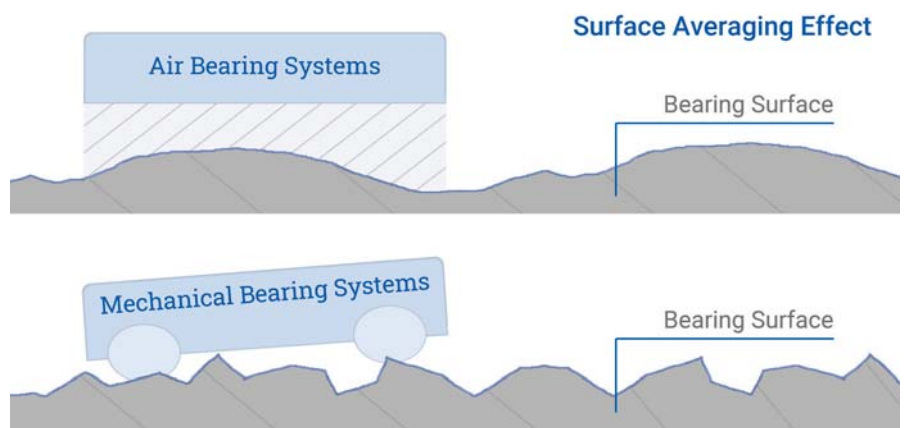


Figure 2: Surface averaging effect of an air bearing versus conventional bearings. PI (PHYSIK INSTRUMENTE) LP

Versus Mechanical Bearings

1. Virtually Unlimited Lifetime, Maintenance-Free, Clean Room Compatible.

Since air bearings work without mechanical contact between components, they do not deteriorate and thus do not require periodic inspections, maintenance or relubrication cycles. Also, unlike with cross-roller bearings, there is no risk of cage migration, especially when small repetitive motion cycles are executed.

Due to the absence of friction and lubricants, these systems also fulfill the requirements for clean room applications.

2. Motion with Excellent Geometric Performance and Extremely Small Straightness, Flatness and Eccentricity Errors

Air bearings provide high accuracy, owing to the high precision manufacturing process of their components. Due to the surface averaging effect, linear air bearings feature exceptionally flat and straight travel ($0.75\mu\text{m}$ over 500 mm) with minimal roll, pitch and yaw errors ($10\mu\text{rad}$), and rotary air bearings are also superior in terms of eccentricity, wobble and tip/tilt. This makes them highly suitable for manufacturing and measurement processes such as optical inspection, providing excellent repeatability of the same procedure.

This exceptional precision matters for advanced manufacturing processes where every nanometer counts: for example, modern semiconductors are produced with line widths of single-digit nanometers, and even mechanical components in the latest generation of automotive engines can require submicron precision.

3. True-Planar Multi-Axis Motion

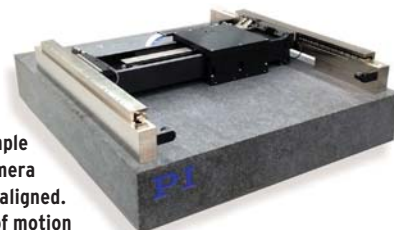
Planar XY stages and XY-theta stages cannot be designed with traditional mechanical bearings. Here, individual axes are usually stacked on top of another. In some instances, XY stages are combined into a single assembly and falsely called planar stages, however the X and Y axis do not use the same reference plane.

The approach of building a multi-axis motion system by stacking individual axes is simple but has several drawbacks. As the upper axis moves to the extremes, it will generate torque loads on the lower axis, leading to geometric errors. In air bearing designs, fully planar XY and XY-Theta positioning systems are feasible, where all degrees of freedom reference to the same base plane and are fully supported over the full travel range.

The A-322 XY-Theta stage for example (see Figure 3) uses one common plane for both X and Y motion, and a flexure joint

Figure 3: The A-322 planar XY air bearing stage also provides 1 degree of Theta-Z motion, ideal for small corrections, for example when a workpiece and a camera or laser system need to be aligned. Straightness and flatness of motion are exceptional and the granite base provides excellent temperature stability.

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on the cross axis even allows for 1 degree of rotation around Z, a great advantage in applications where small alignment errors need to be corrected.

A special gantry control algorithm with a separate Theta-Z control loop in the motion controller takes full advantage of that feature.

4. Motion with Highly Constant Velocity, Vibration-Free and Very High Dynamic Range

The fluid film in air bearings can readily accommodate high velocity, and some air bearings can even improve efficiency at high speed, due to aerodynamic lift effects. Certain processes and experiments, such as semiconductor wafer scanning, 3D tomography and inertial sensor testing, demand constant motion at precisely controlled speeds, where mechanical bearing rumble would introduce unwanted errors.

Figure 4: The A-523 parallel-kinematic Z-Tip-Tilt air bearing stage features a very low profile and can handle loads to 10 kg with rapid acceleration.



In these instances, air bearing systems are the most appropriate solution to provide the necessary continuous motion at minimum speed fluctuations, and they also last longer than mechanical bearings.

5. Long Travel Ranges are Feasible

Air bearings are not limited to short travel ranges, in contrast to another well-known frictionless positioning technology, often used in nanopositioning applications: Piezo flexure guided mechanisms can provide sub-nanometer precision, high scanning speeds and share many of the advantages of air



Figure 5: A compact, hybrid air bearing/mechanical bearing gantry XYZ system. Air bearings are utilized for the cross axis because it is used for high speed scanning. For the slower axes, mechanical bearings are sufficient.

bearings, however their travel ranges are limited to micrometer and the lower millimeter range.

With air bearings, motion ranges beyond 1 m are easily achievable and all the advantages of smaller air bearings are carried over.

6. High Accuracy, Frictionless Motion

In linear motion applications, precise positioning of a moving carriage within a few nanometers is achievable by using a non-contact, direct-drive motor and high-resolution optical



Figure 6: A high-speed voice-coil linear actuator with air bearing guides.
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encoder in combination with an air bearing. For rotational applications, angular resolutions to tenths of arc-seconds are achievable. Here, slotless torque motors are used as the driving force.

Air bearings are often preferred in many inspection, metrology and manufacturing applications due to their minimal hysteresis effect or reversal error, which arises from a lack of mechanical contact and friction. The elimination of friction makes it possible to minimize hysteresis and improve repeatability and accuracy significantly.

Another technology to be considered in precision positioning, with similar performance to air bearings, is called magnetic levitation. Here, magnetic fields replace the function of air as a supporting medium, but control



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Figure 7: A large aperture rotation stage with air bearings. Air bearing rotation stages are often used in semiconductor and optical metrology applications.

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electronics are significantly more complex because all 6 degree of freedom have to be monitored and controlled all the time.

7. Rotary Motion with Minimal Eccentricity and Wobble

Rotary air bearings are highly effective in providing precise rotary motion due to their high stiffness and the aforementioned surface averaging effect. In air bearing rotary stages, wobble or tilt errors typically occur within the range of 0.1 to 1 arc-second—significantly smaller than with mechanical bearing-based rotary stages.

8. Cost-Efficiency

Air bearing mechanisms can also use air pressure to provide

actuation in addition to guidance. This design eliminates additional electric motors, reducing complexity, size and cost.

In general, absence of wear and tear and the need for maintenance is a great advantage, reducing operating cost and improving ROI (return on investment). This may be the most important factor when designing high-throughput automation equipment with 24/7 operation and stringent uptime requirements for years to come.

Summary

Overall, air bearings offer a number of advantages over traditional bearings. They are more precise, accurate and durable. They also operate more quietly and produce less vibration. Air bearings are environmentally friendly and cost effective.

Finally, they can be designed to meet a wide variety of requirements in various industries, including semiconductor manufacturing, precision machining, metrology, aerospace and scientific research. **P&M**

This article was written and contributed by Stefan Vorndran, vice president, marketing, PI (Physik Instrumente) LP.

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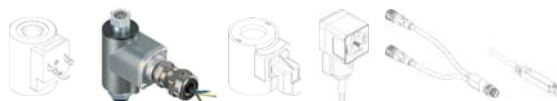




Figure 1: Cell phones are a convenient and popular way for an on-site technician to obtain step-by-step instructions from the remote person and to communicate results. MOTION INDUSTRIES INC.

VFDs & Motors: Remotely Troubleshoot Successfully and Safely

Proper preparation can ensure remote troubleshooting of VFDs, motors and other machine components is performed in a safe and optimized manner.

by Matt Asbill

One of the dilemmas in today's industrial world is finding enough technically capable employees to keep equipment up and running to meet the growing demands of production lines. Many companies don't have the human power or resources for 24/7 on-site maintenance for equipment, especially when it fails due to technical issues.

While modern hardware and electronics offer many avenues for companies to provide access for maintenance and electrical personnel, most will find that this adds complications and expenses that exceed their scope. When placed on a network, HMIs (human machine interfaces), PLCs (programmable logic controllers), VFDs (variable frequency drives), sensors, vision systems and other devices allow approved personnel unlimited access to data from almost anywhere in the world.

This connectivity can enable remote troubleshooting of machine components such as VFDs and motors, helping to overcome the challenges of limited technical resources when a maintenance issue arises. However, there are several aspects which need to be taken into account to ensure safe and successful remote troubleshooting.

The Challenge: Who Will Maintain the Equipment?

As production demands increase, the shortage of workers, especially those with higher technical capabilities, has forced companies to assess their after-hours responses to breakdowns and failures. For example, they may only have one person who knows how to evaluate PLC code or understands the layers of VFD parameters. When this person goes home for the day, what happens when a problem arises beyond the knowledge level of the maintenance person now on the clock?

In a perfect world, a qualified technician would cover all shifts, but that is not always possible.

Distance can also be a factor, where certain employees may live close enough to be called in for technical support, while others may live impractically far away. Or, with certain OEMs and companies with multiple locations, the most qualified person to analyze the problem may live hundreds of miles away.

Proper Maintenance Preparation

The first step companies should consider for failure events is proper preparation. This comes down to identifying which

production lines or equipment must keep running and what steps should be followed when things go wrong.

Assuming that a plant may not have enough technicians or mechanics to adequately provide round-the-clock coverage, a well-thought-out game plan will shorten the time needed to recover.

An evaluation should include:

1. Identifying the knowledge level or technical expertise needed for each production line.
2. Assessing personnel and their qualifications and responsibilities.
3. Assessing safety, which includes safety personnel, mechanics and electricians familiar with the known dangers.
4. Sharing the location of equipment records, including the lockout/tagout (LOTO) instructions.
5. Deciding if an outside person or contractor is needed for any line.

Each production line's complexity needs to be closely evaluated to determine what requires higher levels of technical support. Are there dedicated employees for each item, or are they considered multi-craft, trained in various electronics and motors?

After the initial assessment of personnel and their required after-hours responsibilities, the highest priority must be given to safety:

1. Are the on-site personnel qualified to work on live electrical circuits or VFDs that have to be powered up to scan through the parameters or fault log? Can they use meters for testing and troubleshooting?
2. Do on-site personnel know the difference between a meter's AC and DC voltage settings?
3. Does the plant have a written lockout/tagout policy with proper items available to the maintenance or electricians throughout the workplace and after hours?

All of this should be decided before a failure so there are no surprises and the dangers are minimized as much as possible.

Often, a local contractor is called in to perform these tasks. Never assume that the outside contractor or technician is qualified for the test equipment. For example, a contractor assigned to the task may be highly trained and experienced in mechanical fields but lack the confidence to successfully test electrical circuits. Listen to the warning signs over the phone, such as, "What setting do I use for the digital meter dial?" or "Where do I put the leads?" or "Can I do this with the power on?" Never push or ask any technician to perform a job or evaluation that they are uncomfortable performing.

Once you decide to call in an outside person, their name and contact information should be available to the plant personnel. The plant personnel responsible for calling should be established in advance to follow the necessary chain of command. This prevents unnecessary calls that could wait until the next day, which may prevent excessive overtime charges.

If needed, staff engineers, technicians or mechanics should have wiring diagrams, assembly drawings, copies of parameters or programs, and other pertinent information. They may be allowed to keep hard copies at home or digital files on their laptops for assisting on-site team members or contractors over the phone.

Most importantly, follow guidelines to ensure that proper personal protective equipment (PPE) is readily available and worn by the on-site worker.

Potential Communication Issues

Modern devices such as Wi-Fi adaptable headsets with visual and audio capabilities—such as a cellphone app for video calls—allow a remote person to see and hear what is happening on site. However, these are not always available or convenient. Take, for example, a motor problem in a compressor room: How do you communicate with someone who needs to wear earplugs in a noisy environment that makes hearing instructions difficult?

The technician must often be given step-by-step instructions, and the results are relayed back to the person helping on the phone (*Figure 1*). This could be accomplished with an assistant or simply waiting for a reply by phone or text.

A brief introduction should be required between the person calling in remotely and the person doing the on-site troubleshooting. Each should know the other's name and at least their phone number in case they get disconnected or need to talk further at another time.

Start by asking the technician if they are okay with performing electrical and mechanical testing, or programming and evaluating parameters. Do they have the tools necessary for the required tasks? Patience will be your highest priority since the on-site person may concentrate on a test procedure, while the remote person may have already presumed the result before receiving the reply. The person on site may not be on the same page as the person acting remotely, so the problem of going down different paths may be the short-term result of improper communication.

How to Get Started with Remote Troubleshooting

Remotely troubleshooting equipment such as VFDs and motors requires experience, but more than that, it requires patience. Jumping to conclusions and ignoring basic safety will only lead to more issues and jeopardize on-site personnel. Never assume that the person on the other end has the knowledge and training to understand and follow basic steps you may take for granted.

This person performing the actual hands-on testing may be a mechanic—not an electrician—so be cautious about how far and in-depth they are pushed to get the equipment back up and running. It is far better to know when to stop the testing process and wait for more qualified personnel to arrive than to place a person or a machine in greater danger.

When beginning the troubleshooting process, the on-site person must ensure that proper PPE is worn. As for the remote person, they must start with the basics. The first question to the on-site troubleshooter should center around what happened before the failure, fault or shutdown. Knowing what was going on right before something went wrong is important.

The remote person must assume that the correct information will not be forthcoming, perhaps even from production workers reluctant to explain a situation that would blame someone for a mistake. More than likely, the person assigned to finding the issue will not know or understand exactly what happened, which is why they are calling someone else in the first place.

Look for simple cause-and-effect situations first, like thunderstorms, power fluctuations, excessive load demands, unusual changes in products and other outside forces that may have played a factor.

Next, it is important to note that many techs or mechanics initially blame the most complicated hardware, like the VFD or PLC. If this piece of equipment has successfully run for a long time, it would indicate that the programming and other related parameters are correct.

For example, a simple blown fuse on the three-phase input of a VFD would still allow it to run. But that would limit its current output, causing an over-current trip that a mechanic may assume was due to a programming error. Many technicians would suspect the motor was bad or overloaded, not knowing that the VFD could run with only two input fuses. Most VFDs will have a fault log history that can reveal a pattern leading to the current failure, even if someone has already pressed the reset button.

It is easy to get pointed in the wrong direction and focus too much on related or unrelated events when the problem lies elsewhere. This makes it especially difficult for a person helping by phone with the testing process, unless they are prepared to ask the correct questions, comprehend the replies, and understand how the multiple paths are related to the core failure event.

As the remote person, you may need to start by checking a motor, depending on its horsepower and voltage ratings. Ask the on-site tech to perform simple checks with a meter, looking for problems or direct shorts (*Figure 2*). Always remember that a megohm meter will put a high voltage into the motor windings to find shorts, but be careful with what range is used to prevent further damage.

As a side note, never use a megger on a motor still connected to a VFD, because the resulting voltage could damage the output transistors. Ask the technician if they can isolate the motor's leads through a contactor or disconnect device. Measure

from leg to leg and each leg to ground to find anomalies or inconsistent readings. In a high-noise area, the on-site tech can write down these readings and move to another area of the plant. Less noise will allow them to communicate with the remote person assisting and analyzing the findings.



Figure 2: The on-site tech can perform simple checks with a meter, looking for problems or direct shorts, and relay the results to the remote person.
MOTION INDUSTRIES INC.

Using a sensor, transducer or other I/O (input/output) often causes problems on another device. A VFD, for example, may use a transducer input inside a feedback loop to determine its final speed. If this transducer fails, the reading may reach zero or maximum value, leading the VFD to run at a minimum or maximum frequency without showing a trip condition.

It may be easier to blame the parameters inside the VFD without realizing it is running correctly based on the faulty input. The remote person must consider these factors and find a baseline to build on. Determine what seems to be working, even during a failure.

The Benefits of Condition Monitoring

Adding various condition-monitoring devices greatly lessens the time required to track down the causes of failure, significantly reducing the need for a remote call. Transducers, meters and other I/O could be added to provide production workers, maintenance personnel and engineers the data required to monitor the equipment while running. This would obtain a baseline and potentially sound the alarm when events start to deviate.

The best solution to remote troubleshooting is to have an established protocol and practice, practice, practice while on site. The safety of an on-site person on the other end of a phone is difficult to ensure, even when you know each other. The remote person called on must imagine what they would do if they were the one performing the work. Sometimes, that may require asking other plant personnel to assist.

The production worker will often know more about the operation and risks but offer their opinion only if asked. Even with a contractor who has been called into a plant, explain what the machine is expected to do and what troubleshooting steps you will take, and detail what to look for.

Even though troubleshooting remotely has challenges, a well-thought-out plan will allow everyone to succeed, especially when everyone goes home safely. **P&M**

This article was written and contributed by Matt Asbill, who has been an automation specialist at Motion for 30 years. Asbill holds a BS in electronic technology from Missouri State University and an MS in engineering technology from Pittsburg State University.



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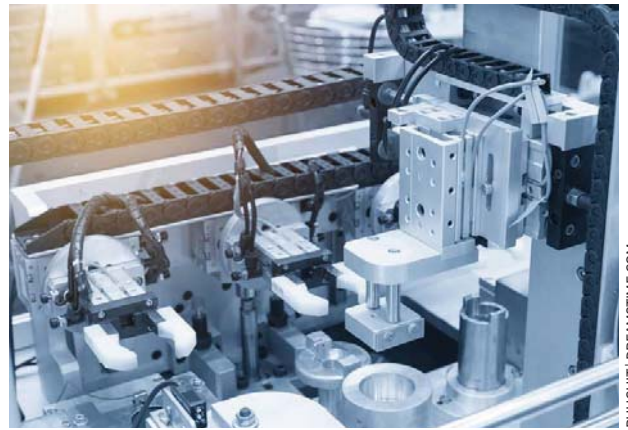
Implementation of digital technologies presents the opportunity to create smarter components and machines for more productive packaging and processing operations.

by Sara Jensen, Sharon Spielman

The priorities of packaging and processing operations have shifted in recent years, with workforce availability becoming the greatest area of concern. As such, it has brought about an increased need for automation and other digital solutions.

Prior to 2020, the focus for many packaging and processing operations—typically referring to consumer packaged goods (CPG) from companies such as Frito Lay and Kraft—was flexibility, quick changeover, productivity and asset reliability. However, once the global pandemic hit in early 2020 “priorities changed significantly,” said Jorge Izquierdo, vice president of market development, PMMI - The Association of Packaging and Processing Technologies, during the National Fluid Power Association (NFPA) quarterly seminar “Advanced Pneumatic Solutions for Packaging Machines.”

Finding those with the knowledge and skills necessary to operate, service and run equipment became



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more difficult, and remains a challenge for this industry as it does for many others.

Because of this, CPG companies are looking to suppliers of automation technology—everything from packaging equipment to components and controllers—for solutions that will help address workforce issues. “That [includes] technologies that are much more intuitive,” said Izquierdo. “The aim is to improve human machine interfaces, make [machines] easier to service and also make remote services [more available].”

Pneumatic systems are a key contributor to downtime in packaging machines, presenting opportunities to improve these systems through digital technologies.

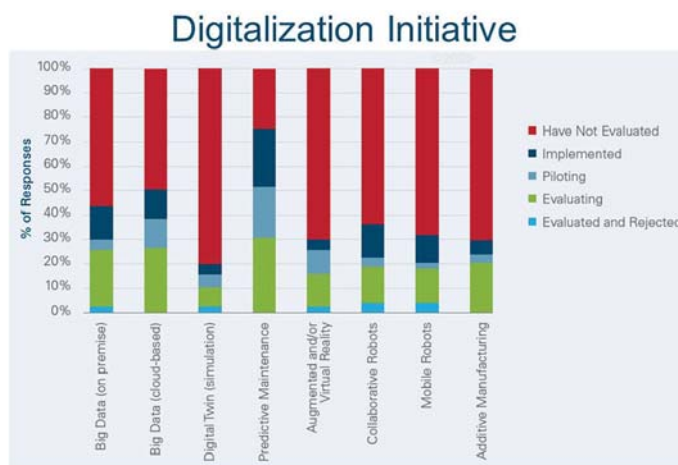
How Technology Can Help Manufacturers

Incorporating intuitive automation solutions can help manufacturers reduce the time it takes to train their workforce so they can quickly get up to speed on using and servicing machines. This helps to maintain productivity, another key priority for many CPG companies.

With the training and ease of use capabilities automation can provide, it can be better assured employees use machinery appropriately and reduce potential downtime issues. According to data from a PMMI member survey Izquierdo shared during the webinar, he said operator error generates

over 20% of an operation’s downtime which is very significant. Being able to minimize downtime with automation can greatly benefit manufacturers.

Automation and other digital solutions also offer the possibility of shortening the time it takes to service a machine. Use of intuitive graphic images or augmented reality glasses can help guide workers through the appropriate steps to follow to fix a problem, enabling them to address it more quickly.



A PMMI member survey showed CPG companies are investing in various digital technologies, particularly predictive maintenance solutions as they are the easiest to implement and see immediate benefits.

PMMI - THE ASSOCIATION OF PACKAGING AND PROCESSING TECHNOLOGIES

Often these systems can quickly identify the issue, or help in determining what it is, further simplifying and thus quickening the servicing process.

Justin Katz, manager, Product Management Vacuum Automation at Schmalz, Inc., who also presented during the NFPA seminar, said his company is seeing increased demand from the market for integration of digital solutions such as software and apps which can quickly provide users with insight into what is happening with their industrial equipment. Many of the company's products are pneumatics-based and are now integrated with analysis and diagnostic functions to make them easier to use.

"It means you can buy this product and right out of the box it's going to have some of this next-generation intelligence built in so you can have information exchange right on the device," he said. "It gives you a condition monitoring function that you maybe didn't have with a more basic type of component. This is really powerful because you can [install the component] and immediately start realizing the benefits."

Increased Adoption of Remote Accessibility

Prior to the pandemic, much of the equipment CPG manufacturers were using in their plants had the capability to be accessed remotely but was not being used consistently, said Izquierdo. The lack of understanding between the information technology (IT) and operations technology (OT) parts of the business as well as cybersecurity concerns were key factors.

"There was a significant hesitation to provide that access," he said.

However, this all changed when the pandemic occurred, and service technicians were not allowed to enter manufacturing facilities. "All these priorities changed significantly and suddenly remote access and embracement of [new] technologies exploded."

Doing so helped many CPG manufacturers maintain their business during the pandemic as any downtime could have significantly hindered their operations. Allowing service

Which of the following automation components most commonly cause downtime through failure?



PPMI surveyed its members to find out which machine components were the most common cause of downtime. Industrial sensors and pneumatic systems were the top responses.

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technicians to remotely access their machines enabled issues to be addressed as they happened so a machine could be back up and running as quickly as possible.

According to Izquierdo, adoption of remote access technologies has been one of the biggest changes to take place in the packaging and processing industry in recent years. This trend will likely continue due to the ease it provides all parties involved and the lack of qualified technicians in the field—another aspect of the workforce challenges facing so many industries.

Determining the Cause of Downtime

PPMI's survey data showed packaging machinery is the most likely cause of downtime in a CPG company's operations, necessitating use of tools to help mitigate it. Decorating and coding equipment is the main culprit for downtime, according to the PPMI survey results, followed by filling and dosing equipment and then form, fill and seal equipment.

There are many reasons for these machines experiencing downtime issues—such as operator error and general



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wear-and-tear—but when drilling down on specific machine technologies, survey respondents said industrial sensors were the number one cause followed closely by pneumatics.

Izquierdo said these results are interesting given the increased use of sensors for data collection and the growing adoption of the Industrial Internet of Things (IIoT). “It’s interesting we’re going in that direction, and we still have some homework to do involving industrial sensors,” he said.

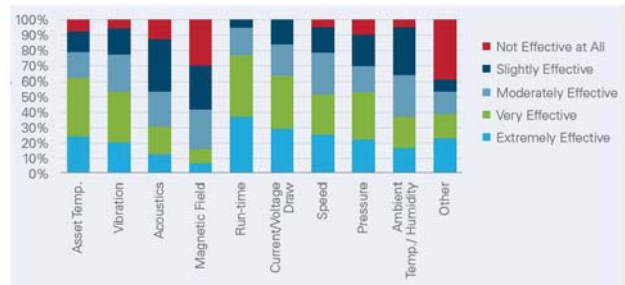
In addition, he said there is likely “opportunity to make those pneumatic systems smarter” to help reduce the amount of downtime they are causing in packaging machinery.

Predictive Maintenance Leads Digitalization Initiatives

Most CPG companies are doing in-house maintenance, as indicated in the PMMI survey, which Izquierdo said is very common. Maintenance strategies vary—about 35% of survey respondents said they use portable equipment for measuring aspects such as temperature and vibration, 45% have sensors integrated in their machines and about 30% use run-to-fail for at least some of their machines.

More than 50% of respondents said they consider their maintenance strategy to be optimized, which Izquierdo said

Which types of data OEMs and integrators feel would be most useful for predictive maintenance



OEMs and system integrators view run time, current and voltage draw, and speed as the most valuable machine aspects to monitor when developing predictive maintenance tools according to a PMMI survey.

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is an interesting number considering 30% of CPG companies are running their equipment to fail.

While many companies consider their maintenance strategies to be optimized, the PMMI survey also showed predictive maintenance technologies to be the top digital solution in which they are investing resources—demonstrating the further optimization it could bring. More than 40% of respondents said they are piloting or implementing it, and another 30% are evaluating it. “That’s where most of the

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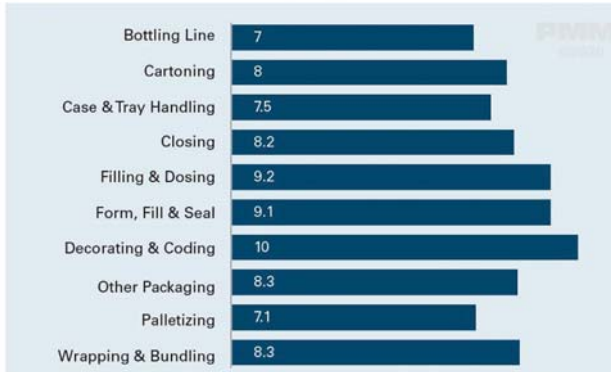
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Which types of packaging machinery are most likely to fail ?



Aggregated results using a weighted index

A PMMI survey of CPG companies found the types of packaging machinery which were most likely to fail were Decorating & Coding followed by Filling & Dosing.

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companies are finding the...low-hanging fruit for digital technologies,” said Izquierdo.

As part of its survey, PMMI asked OEMs and system integrators what they were measuring in order to implement their predictive maintenance solutions. Run time, current and

voltage draw, and speed were noted as the most valuable when developing predictive maintenance tools.

OEMs and system integrators see the highest revenue potential in predictive and preventative maintenance solutions as they can help to prevent downtime and thus increase productivity—leading to more goods produced and sold. Remote assistance was also highly regarded by these survey respondents, further demonstrating the importance of keeping machines operational.

The PMMI survey showed CPG companies are investing in other digital technologies as well such as big data, digital twins, augmented reality and others, but given the productivity benefits and revenue potential of smarter maintenance solutions, adoption of these digital technologies will likely remain high in the foreseeable future. They should therefore also be an area of focus for developers of pneumatic systems and other technologies used in or with packaging machinery.

“The point is the demand for predictive maintenance and remote assistance is there, as well as the opportunity to create smarter components and pieces of equipment,” concluded Izquierdo. “I think there is business to take advantage of and great opportunity for component manufacturers, OEMs and system integrators to provide better solutions to [the packaging and processing industry].” **P&M**

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The Current State of Battery Technology

Continued research and development into battery technology is expanding the market opportunities for electrification.

by Sara Jensen

Battery technology has evolved over the past several years, helping to bring down costs as well as expand the applications in which electrification can be applied. As batteries for mobile applications are used either in conjunction with a downsized engine as part of a hybrid powertrain or in place of an engine in full-electric architectures, they play an important role in powering a machine and its systems—including the hydraulics and pneumatics.

Although there are solutions which eliminate fluid power systems, in many applications they will remain an important component because “the best operating systems will still require functionality that only fluid power can deliver,” said Brett Engelland, director of sales for Electrification, and Nick Moore, director of product management for Electrification, at Vanguard, in an interview with *Power & Motion*.

Given the growth of electrification in so many vehicle and mobile equipment applications, and the impacts it will have on the design of hydraulics and pneumatics, it is important for those in the fluid power industry to understand where battery technology currently stands.

Common Battery Types

Lithium-ion batteries are the most commonly used battery type in hybrid and electric vehicles as well as other applications. Their chemistry offers high energy output and efficiency, good high-temperature performance and a high power-to-weight ratio, among other benefits, all of which is suitable for a range of use cases.

While lithium-ion has its benefits, it also presents challenges. According to research firm IDTechEx, the current versions



of lithium-ion may be reaching their performance limits but new developments in cell materials and battery designs could help overcome these.

One possibility is shifting from the currently used graphite anodes to silicon which could provide significant improvements in energy density and performance, stated IDTechEx in a press release reviewing findings from its report “Advanced Li-ion and Beyond Lithium Batteries 2022-2032: Technologies, Players, Trends, Markets.” Though it has been difficult to use larger quantities of silicon due to stability and cycle life issues, the research firm said improvements in silicon anode technology over the last 10-15 years is now enabling 5-100% silicon in the anode.

Use of new additives and electrolyte formulations is another way IDTechEx sees improvements to lithium-ion batteries being achieved. It noted one company which is utilizing phosphazenes and phosphorous-nitrogen compounds to help improve safety and performance.

Creation of more space efficient battery packs could also bring performance improvements. IDTechEx said several

companies in the automotive space are working on batteries with cell-to-pack designs which eliminate the materials used for module housings; this will lead to a more optimized package as well as improved energy density and battery integration for OEMs. It noted BYD has advertised the potential to improve volume utilization by 50%, from 40% to 60%, and battery manufacturer CATL has announced its latest cell-to-pack design could achieve a 72% volume utilization.

Other commonly used battery chemistries include nickel-metal hydride and lead-acid. According to the U.S. Department of Energy (DOE), nickel-metal hydride batteries provide reasonable specific energy and power capabilities which suits use in computer and medical equipment. They have a longer life cycle than lead-acid, and have been used in hybrid-electric vehicles, but are challenged by their high costs and heat generation at high temperatures. Lead-acid, meanwhile, can offer a high power and inexpensive, safe option but its low specific energy and poor performance in cold temperatures, as well as its short lifespan, reduces its application use.

Research into Alternative Chemistries

As no battery chemistry is perfect, an array of research is taking place into other potential chemistries. For instance, most of the components which make up a lithium-ion battery can be recycled, but doing so remains costly to date, which is currently a challenge for the industry. Lithium-ion also has a high cost; the battery of an electric vehicle or machine is the most expensive aspect—even as their prices have come down in recent years—challenging the uptake of electric-powered vehicles.

The DOE's Pacific Northwest National Laboratory is developing a sodium-ion battery which so far has shown promise in large-scale applications. By adjusting the ingredients which make up the battery's liquid core as well as using a different type of salt, the researchers have shown the potential for a chemistry with extended longevity which could also be a more environmentally friendly option.

Though still in the research and development stage, the battery has demonstrated what other chemistry possibilities could be available in the future.

Researchers at the Tokyo University of Science (TUS) are investigating magnesium as an alternative to lithium ion for solid-state batteries. Among the challenges with the latter is the fact lithium is a rare earth metal—ever-increasing demand for batteries will lead to it becoming more scarce; there are also environmental concerns related to the mining of rare earth metals which questions how “green” a battery technology is.

Magnesium, however, is an abundant material, but to date its use in practical applications is limited due to the poor conductivity of magnesium ions in solids at room temperature. The researchers at TUS may have overcome this challenge by using metal-organic frameworks (MOFs) which have highly porous crystal structures. This enables efficient migration of the included ions and thus improves the level of conductivity possible.

As explained in a press release from TUS about the research, the team used a MOF known as MIL-101 as the main framework and then encapsulated magnesium ions in its nanopores. In the resultant MOF-based electrolyte, magnesium ions were loosely packed, thereby allowing the migration of divalent magnesium ions. The electrolyte was exposed to acetonitrile vapors, which were adsorbed by the MOF as guest molecules, enabling further enhancement to the material's conductivity.

Research is ongoing with this material, but testing has shown high levels of conductivity and the potential for this technology to be used in future battery applications.

More Battery Options Increase Use Cases

Although electrification is more commonly associated with passenger vehicles, its implementation in heavy-duty trucking and off-highway equipment—key markets for fluid power, hydraulics in particular—has grown in recent years due in large part to advancements in battery technology. Batteries are now better able to meet the power demands of these larger vehicles while continued reductions in battery prices have helped make them easier to implement.

At bauma 2022 and CONEXPO-CON/AGG 2023, it was evident how much electrification of construction equipment has grown in recent years. With that has come new technology partnerships and battery solutions. Danfoss Power Solutions, for instance, announced at bauma its partnership with battery provider Webasto. The companies will bring together their technological expertise in electrification to aid OEMs with

the development of electric-powered machines.

Aiding the move to electric power systems in the heavy equipment market are developments of batteries specifically for this segment. Off-road machinery has its own unique requirements, use cases and challenges; simply plugging an automotive battery into a piece of construction equipment will not work. Therefore, companies like Xerotech—which showcased its technology at CONEXPO 2023—are developing batteries which meet the specific requirements of heavy equipment.

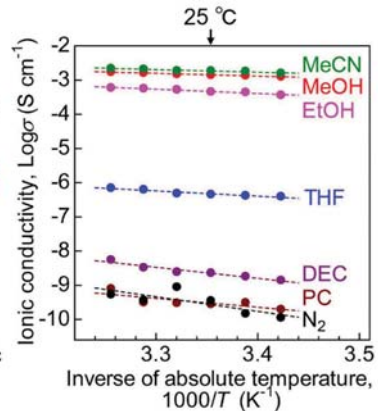
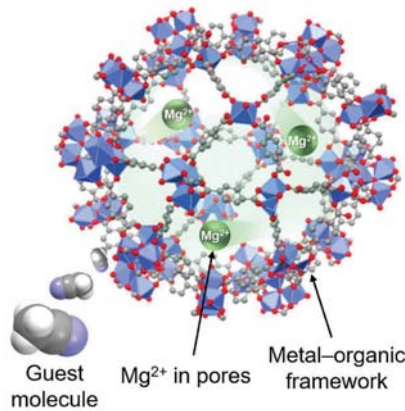


The latest generation ELEO battery includes an advanced battery management system. YANMAR

Several engine manufacturers serving the off-highway equipment market have also begun developing batteries. Their understanding of the market's power requirements aids with these developments while enabling them to provide customers with a range of power system options. For instance, Briggs & Stratton started developing its Vanguard Commercial Lithium Ion Battery pack in 2019, and continues to add new battery models to meet varied applications.

While some companies have chosen to develop battery technology themselves, others have acquired it. This helps to speed up development because the acquired company can bring its battery expertise together with the engine manufacturer's knowledge of the off-highway industry, ensuring optimized solutions are developed.

In February 2022, John Deere acquired a majority ownership in battery technology company Kreisel Electric Inc.



Development of a new magnesium ion conductor consists of a metal-organic framework holding magnesium ions in its pores. A "guest molecule" acetonitrile is introduced into the structure to accelerate the ionic conductivity of magnesium ion and allow its migration through the solid.

MASAAKI SADAKEYO FROM TOKYO UNIVERSITY OF SCIENCE

Since then, the two have partnered on the development of battery systems for off-highway equipment. Three new concept batteries were displayed at CONEXPO 2023 which included 20 and 40 kWh power options. Both batteries provide a modular architecture to aid integration by OEM customers as well as Kreisel's patented immersion cooling technology.

At CONEXPO, ELEO Technologies—acquired by engine manufacturer Yanmar in April 2022—introduced its new generation of battery systems. According to ELEO, the new battery system features state-of-the-art cylindrical cells combined with optimal packing flexibility to provide high energy density and run times between charges. The battery is modular in design to accommodate an array of machine applications and power needs ranging from 50-800V and 10-1,000 kWh.

Performance Insights Benefit Design

To aid with the implementation of batteries, no matter the type of chemistry or application, technology and engineering services company WAE Technologies has launched its Elysia battery intelligence software. The software is designed to provide insight into battery performance as well as management of its performance.

Two products are available, Elysia Embedded and Elysia Cloud Platform. Elysia Embedded offers battery management algorithms which can be run directly on a battery's BMS (battery management system). These algorithms can be used by OEMs to increase an electric vehicle's range, enable faster charging and maximize battery power, states WAE in its press release announcing the launch of the software.

Because the software uses physics informed models for its algorithms, WAE says applications to date have shown the



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ability to bring up to a 30% increase in battery life and 10% potential increase in battery range.

In the previously mentioned IDTechEx report on lithium-ion batteries, the research firm notes improvements to a BMS can bring about performance improvements without the challenges associated with materials development.

The Elysia Cloud Platform uses proprietary digital twin technology to help OEMs, fleet managers and those investing in battery technology gain insights into battery performance. It provides a complete picture of a battery's state of health to better determine how it is working in an application as well as any degradation occurring—a factor important to a battery's potential use in secondary applications, such as grid storage, once past its useful life in its initial application.

Ensuring battery efficiency is a critical area of development for many in the industry. How much charge a battery holds is an important aspect of this, but today proves challenging with currently available sensor technologies.

Researchers at the Tokyo Institute of Technology (Tokyo Tech), however, have developed a diamond quantum sensor-based detection technique to improve the accuracy of determining a battery charge. Per a press release from Tokyo Tech about the research, commercial sensors used to detect current output of the battery (how the charge state is measured) are not able to measure small changes in the current at milliamper levels. This leads to an ambiguity of around 10% in the battery charge estimation, states Tokyo Tech.

The diamond sensor can estimate the battery charge within 1% because it is able to measure currents at milliamper levels which current commercial sensors are not capable of doing. This provides a more accurate reading of battery charge.

By more accurately detecting battery charge, the researchers say usage efficiency can be increased. They also see the possibility of reducing running energy and battery weight—because it can now be more accurately sized for an application.

With the various advancements taking place in battery technology, improvements in electric vehicle and machine designs can be achieved. There are of course still many challenges associated with batteries and implementation of electrification, such as the sourcing and production of battery

materials and the amount of energy required to recharge the growing number of electric vehicles—but as technology continues to evolve, efforts are being made to overcome these challenges while bringing solutions to market which meet both performance and environmental requirements. **P&M**

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An Exciting Time for Tribology and Lubrication

The technological challenges brought about by industry trends such as sustainability and digitalization are making it an exciting time to work in the fields of tribology and lubrication.

by Sara Jensen

Continued growth of major trends such as electrification and digitalization are bringing new technology and developmental needs to a range of industries, including tribology and lubrication.

Hong Liang, Ph.D., Oscar S. Wyatt Jr. Professor in the J. Mike Walker '66 Department of Mechanical Engineering at Texas A&M University, said these trends and the development challenges they bring are helping to make it an exciting time to be working in the field.

Liang has spent her career in the field, and currently focuses her research on tribology's fundamental and application aspects. In May 2023, she was appointed president of the Society of Tribologists and Lubrication Engineers (STLE) for a one-year term. In this role she will work together with the 2023-2024 executive committee to implement STLE's strategic plan, part of which is focused on further promoting the role tribology plays in a range of applications.

Power & Motion recently spoke with Liang to learn more about what she'd like to accomplish during her tenure as president of STLE as well as trends she sees impacting the tribology and lubrication industry.

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

Power & Motion: What are some of the major trends you are currently seeing either in or impacting the tribology and lubrication industry?

Hong Liang: I see the short-term impact, right now, is with supply chain issues. There's suddenly not enough raw material for us to work with to make products, or if

we have the product it has to be shipped to the customers [which can present cost and other challenges]. And that is considered the immediate impact we have to deal with. So, the industry has a lot of different ways [to address these impacts] such as finding ways to collaborate and localize some production. Companies use what local resources they have... [which could lead] to finding a new, local customer or supplier, helping to solve supply chain issues, as well as not having to ship product too far to customers. Another part of it [is the potential] to find ways to run more efficiently and use less energy to be more sustainable.

Now you see a lot of electric vehicles coming out; almost all the car manufacturers have some kind of electric vehicle...to meet the demand. I think [for electric vehicles] we probably need better and more lubricants—one for the car, one for the electrical system and one for the mechanical system. Everybody is competing [to create] the best fluid to make electric vehicles run better. [These lubricants need to provide] better thermal management to protect electronics. This is one major area I have seen companies trying to get into [the electric vehicle space]. It has to be done [lubricant development] quickly, maybe using an entirely new approach to get [product in the market]. I see the industry moving pretty fast, that's a very good sign.

The other area [impacting tribology and lubrication] is sustainability—new chemicals replacing the forever chemicals and reducing the carbon footprint of manufacturing products. The digital revolution for manufacturing, Industry 4.0 and now getting [into] 5.0 and 6.0... the computation, robotics and data science are all coming into play. So, there's a lot

of things going on, we are [working] in the areas that are actually quite exciting.

P&M: What are some of the challenges the industry is facing currently, and how might these be overcome, either through work STLE is doing or the industry in general is doing?

HL: We're definitely facing a lot of challenges, even more than before. Still using electrical vehicles as an example... there are certain types of challenges we don't anticipate. Because electric vehicles have not been running on the roads for too long, we don't really know the lifespan for the fluids [and other components]. I think the challenge may just be the lack of knowledge of that. STLE is a good place you can come to learn. The more we learn, the more we can [understand about fluid lifespan in electric vehicles].

There are so many different, more challenging requirements from electric vehicles for the fluid—you have to have a certain type of electrical insulation or connectivity and also you have to have enough thermal [management] to extract all the heat buildup in the drivetrain. And also, you still have to have corrosion protection and friction reduction. Meanwhile, you also have to do [all this] in a low-cost fashion. We have never had that kind of requirement in one product, so that is certainly technically challenging and also exciting. Who is going to solve [this development] problem? Probably not one company, the entire field needs to contribute. **P&M**

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