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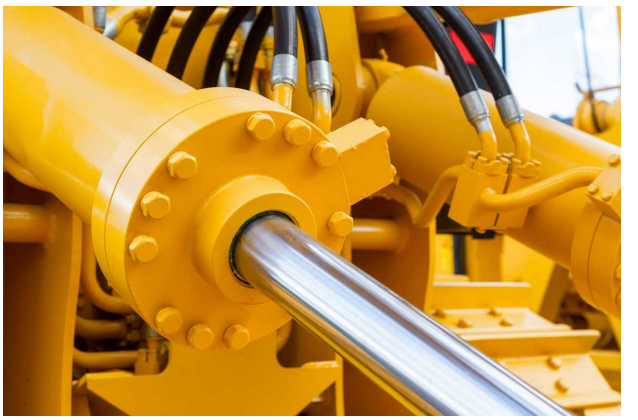
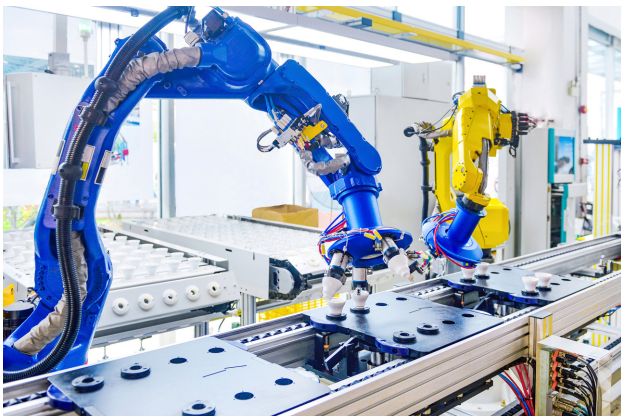
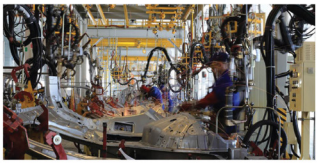
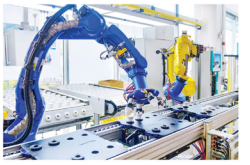
THE STATE OF FLUID POWER AND ELECTRONIC MOTION CONTROL





THE STATE OF FLUID POWER AND ELECTRONIC MOTION CONTROL



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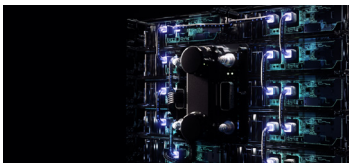
MONITORING MARKET and technology trends is a valuable way to not only stay on top of what is happening within the fluid power and electronic motion control industry, but also offers insights that can help with the planning of future system designs.

Sara Jensen,
Technical Editor,
Power & Motion

Despite calls for a recession in 2024, there remains optimism for these markets. There will be opportunities to breathe after the whirlwind that was the last 3 years of working to meet amplified demand. This will be important because the rest of the 2020's are expected to see strong growth.

Within this eBook you'll find articles which examine the current state of the industry as well as insights on what factors will drive future market growth to help you plan your own business strategies for the coming year.



THE STATE OF
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CHAPTER 1:

Positive Outlook for Fluid Power Despite Electronics Making Inroads

SARA JENSEN, Technical Editor, *Power & Motion*

As more electric options come into play and an economic slowdown is expected, positive sentiments remain for the hydraulics and pneumatics industry.

After a few years of strong growth, the consensus is that the global economy is headed for a slowdown in 2024. However, a positive outlook remains for the fluid power and electronic motion control sectors as efforts to electrify vehicles and machines continue as well as infrastructure and reshoring projects – all of which will help drive demand for motion control components.

Technological advancements taking place in hydraulics and pneumatics will benefit the market as well. Improved efficiency, more compact designs and increased power density are just some of the areas of focus which will help meet customer and market needs going forward.

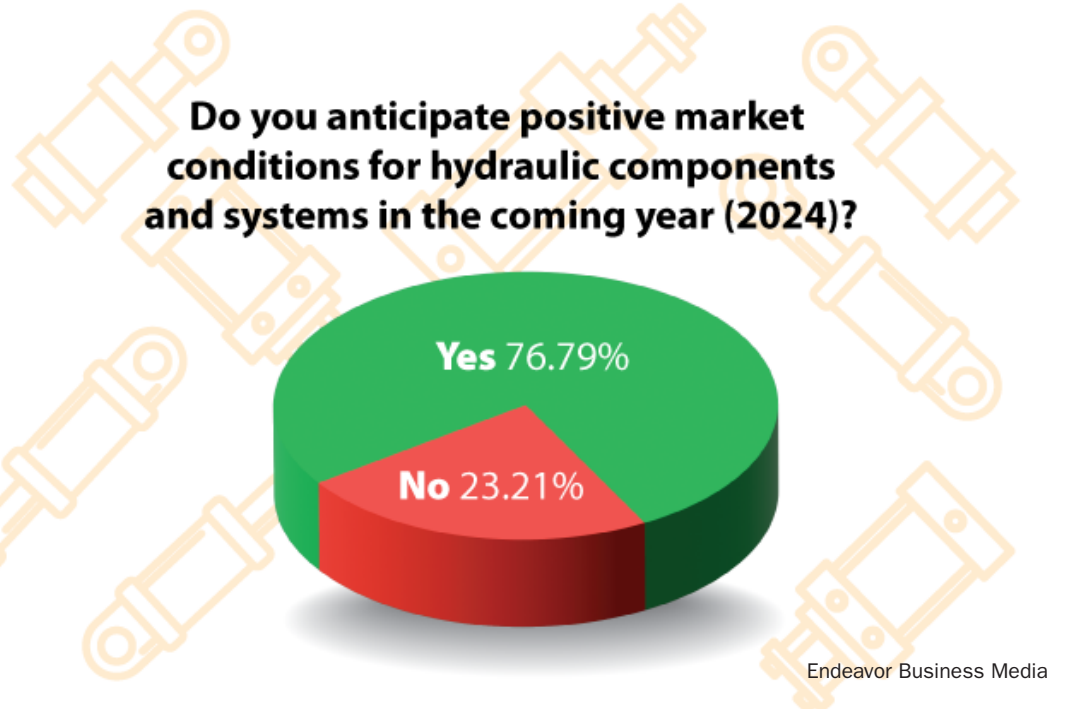
Even as electronic alternatives start to make inroads in more applications, there are still many instances where hydraulic or pneumatic solutions are the preferred option. Both types of motion control technologies will see continued growth in the coming years as each offers unique benefits which suit the various applications they serve.

The greater integration of electronic and fluid power technologies will benefit the market as well by bringing new performance capabilities to help meet the evolving needs of customers – including those developing electric and autonomous vehicles.

To get a better sense of current and future market trends, *Power & Motion* surveyed its audience as well as spoke to several members of the industry to gain their insights on the state of fluid power and electronic motion control.

Demand for Hydraulics will Remain Strong

The majority of respondents, 77%, anticipate positive market conditions in 2024 for hydraulic components and systems. Many noted the technological advancements taking



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place in the industry as a reason for its expected positivity, as well as the move to electrification and automation – both of which will still require hydraulic components.

One respondent even said the rush to electrify everything is actually increasing demand for traditional products. Another noted the continued electrification of hydraulics and enhanced power versus weight ratios will positively affect hydraulics growth.

Continued demand in the oil and gas markets and the need for hydraulics in the construction equipment being used for infrastructure projects and building of new manufacturing facilities will benefit the market as well.

Ken Baker, CEO of Baily International, said the company is predicting a soft landing for the hydraulics market in 2024 as the economy slows down. Availability of components was a large market driver over the past 2-3 years but that is starting to normalize, which will play into the expected market slowdown.

"We're more optimistic than some people in the industry in general, but we are seeing it slow down. And I think that's going to be the key to watch," said Baker. "We're trying to keep a careful eye on our inventory, because you can get ahead and inventory too much, but you don't want to be caught short when you see the rebound coming."

For the 23% of respondents who do not believe there will be positive market conditions in 2024, several noted the market slowdown as a reason, as well as competition from electronic options.

Jeff Herrin, senior vice president of Research, Development, and Engineering at Danfoss Power Solutions, said borrowing costs could have an impact on the hydraulics industry in 2024. "Interest rates are unusually high, which could delay machine purchases due to financing costs. While temporary, this affects not just OEMs, but many others in the supply chain."

He also noted single- and multi-family housing construction is slowing down and there is significant fluctuations in grain and commodity prices – both of which could impact the construction and agricultural equipment markets, the largest customer segments for

hydraulics.

As such, Herrin said Danfoss is predicting a down cycle for mobile machinery but in other customer segments limited growth. He agreed with Baker that the good news in the market is the supply chain disruptions are largely gone "and we're getting back to the market fundamentals of borrowing costs and supply and demand. This is the first time in 3 years we can say that."

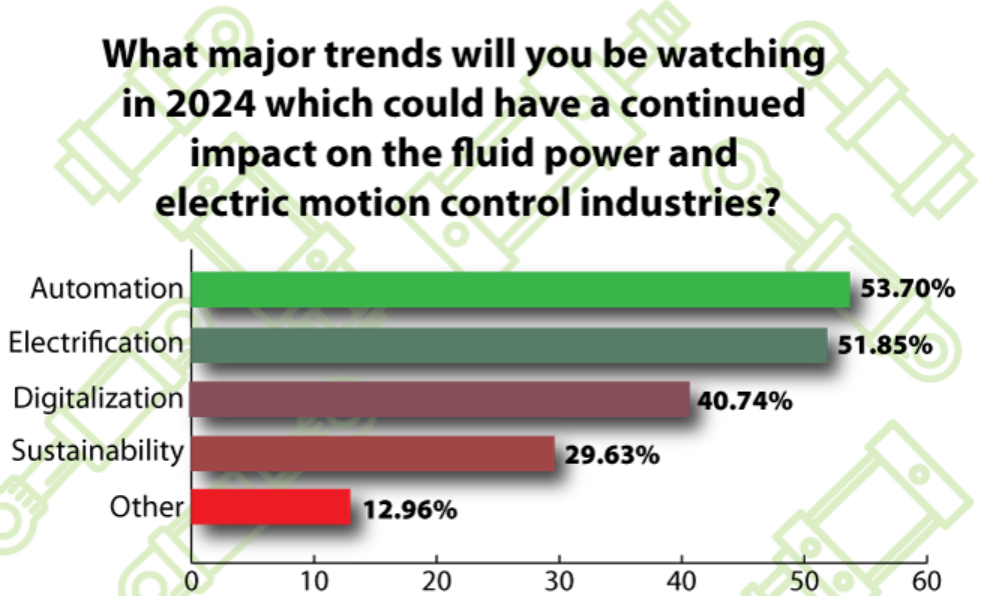
On the technology side of things, it is clear the integration of electronics and continued trend toward electrification are having an impact on the hydraulics industry. According to Matteo Arduini, President of Hydraulics EMEA (Europe, Middle East and Africa) and Rick Martich, President of Hydraulics, Americas and SVP, global Operations and Systems Sales at Helios Technologies, one of the most significant developments in the industry is the rise of electrohydraulics.

"The market is moving away from defining and specifying hydraulics and electronics in isolation," said Arduini and Martich in an interview with *Power & Motion*. "Instead, there is a push for these elements to be integrated into intelligent systems that offer enhanced efficiency and functionality."

Baker said Bailey International sees a continued electrification of hydraulic circuits but doesn't foresee a replacement of hydraulics by electrical products because of the physics involved. "But we do see more sensors, more controls, more electrohydraulic valves, and more monitoring of the system. And we're seeing that move from the high tier ones down in the middle market."

Energy efficiency is a key area of development as well according to Herrin, both on a component and system level. "At Danfoss, it's been our experience that the bigger efficiency lever is at the systems level because we can optimize machine operation, and therefore power consumption, through software and electronics," he said.

Tim Bankhead, Application Engineering Manager, North America at HydraForce/Rexroth, a Bosch Company, said energy savings is a perennial concern for the company



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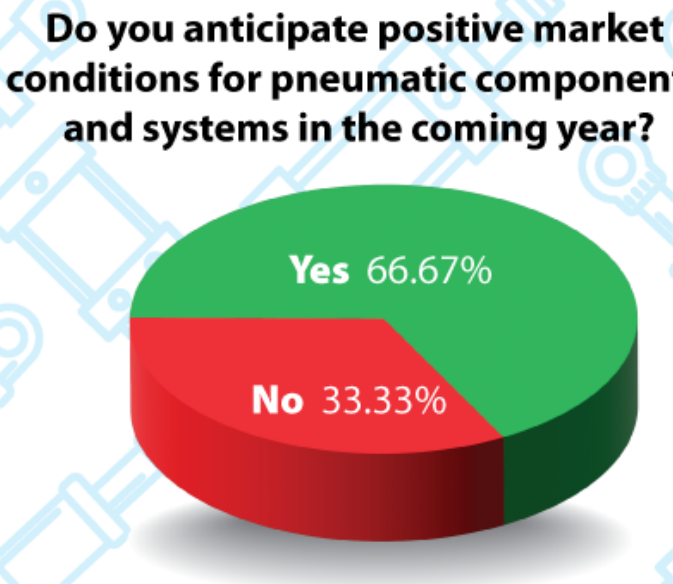
and its development efforts.

"The best minds in fluid power are finding ways to create more compact, powerful, energy-saving and sustainable solutions to address the application of hydraulics regardless of the power technology driving those machines," he said.

Technology Advancements to Benefit Pneumatics

Those in the pneumatics sector also anticipate positive conditions in 2024, though just 67% of survey respondents indicated as such. Some of the reasons respondents said they see continued positivity in the market include the lower energy costs associated with pneumatics as well as the faster motion and response possible with these systems.



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It was also noted that the continued integration of pneumatics with robotics will benefit market growth as well as additional pressures in the manufacturing industry to be efficient which pneumatic systems can help achieve.

For the 33% who do not see positive conditions for the pneumatics market in 2024, reasons included the anticipated economic slowdown as well as decreased demand for these components and electrical options replacing pneumatics in some instances.

Similar to the hydraulics market, there are several economic factors which could negatively affect the pneumatics sector such as commodity prices and high interest rates said Melissa Childers, Business Development Manager, Motion Systems Group, Pneumatics Division at Parker Hannifin. However, she said she expects the pneumatics market to strengthen in performance in 2024.

"We are seeing growth from the previous year in our system solutions for our door systems for the bus and coach market as well as our CTIS [central tire inflation system] technology," she said.

Rex Bateman, Director of Engineering at SMC Corp., said ongoing labor strikes and

the continuation of a soft market could present economic headwinds for the pneumatics industry in 2024. The semiconductor industry, which utilizes pneumatic systems, is currently experiencing a significant slowdown, he said, and it may be late 2024 before it starts to recover.

But overall, he sees the pneumatics market continuing to grow as the need for automation rises as pneumatic components can play an important role in these systems. In addition, there are opportunities for the use of pneumatics in alternative energy and sustainability solutions.

Several advancements in pneumatic system designs have increased their capabilities. Bateman said SMC has improved its pneumatic actuator designs to increase controllability in positioning, speed, acceleration and deceleration which could offer advantages over electric solutions.

Frank Langro, Director - Product Market Management, Pneumatic Automation at Festo North America, said improvements in force control is one of the development areas that will impact pneumatic systems going forward. One way in which Festo has addressed this is using piezo electric technology instead of the more commonly used solenoid pilot valve.

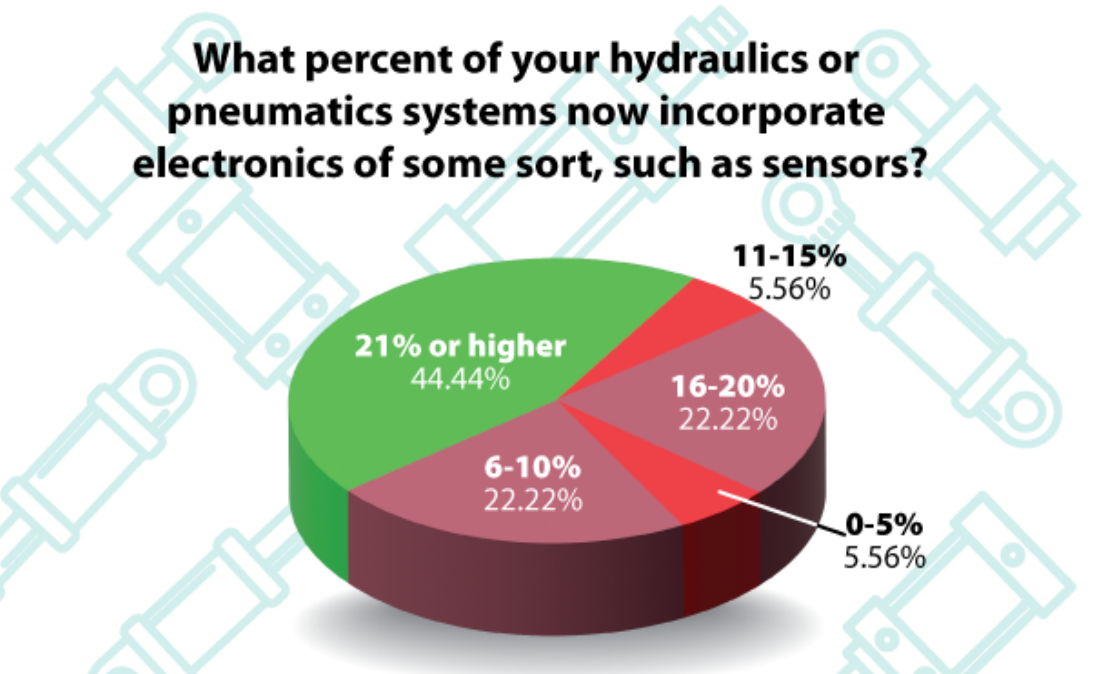
"Piezo technology enables precise control in processes such as wafer polishing and battery winding. Improvements to these processes reduce waste and are vital as the demand for semiconductors and rechargeable Li-ion (lithium-ion) continues to rise," he said.

In addition, Langro said piezo pilot valves use up to 95% less energy than solenoid valves which helps meet the growing industry trend toward increased energy efficiency.

Visit our State of the Industry hub for the full Q&As with the industry experts featured in this piece as well as video interviews and additional industry insights.

Electronics Bringing New Capabilities, Alternative Technologies to Market

Integration of electronics within fluid power systems is increasing. Forty-four percent of respondents to *Power & Motion's* survey said that 21% or more of their hydraulic and



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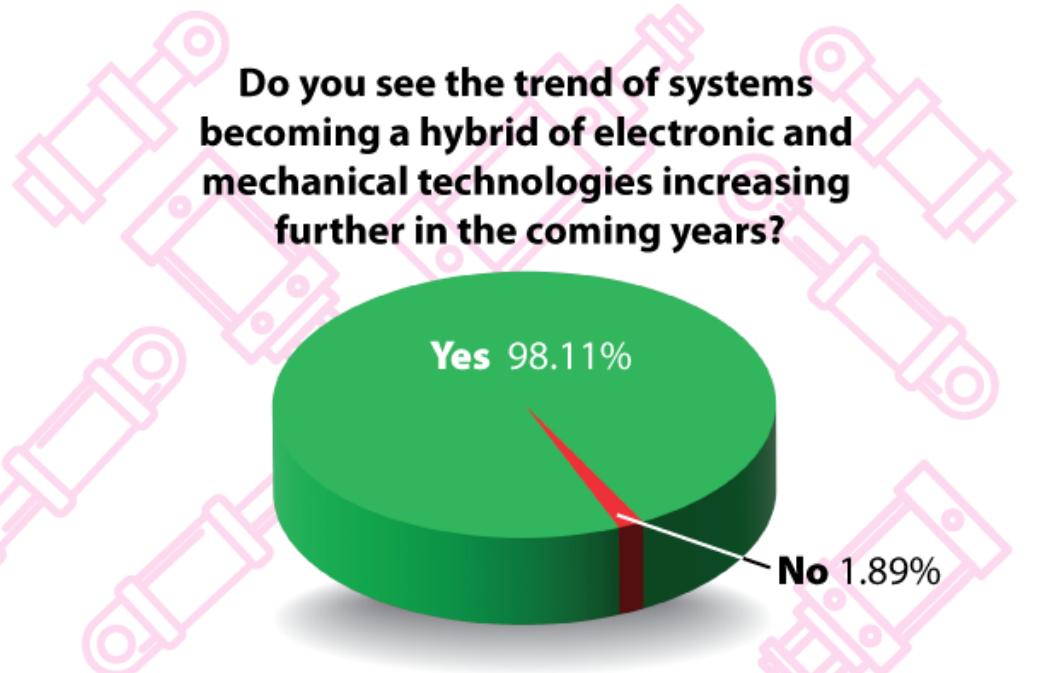

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pneumatic system designs now incorporate electronics of some sort such as sensors. This was followed by another 44% who were split between 16-20% and 6-10% of their systems incorporating electronics.

Each of the industry members we spoke to also said they see this trend increasing. In the case of sensors, their use can aid with enabling more precise movements of hydraulic and pneumatic components as well as gathering of performance data to help improve maintenance. Festo's Langro said that today the information coming from many devices not only detects failures but also helps to predict them, minimizing downtime and thus costs for end use customers.

Baker said the rising use of sensors is helping meet customers' desire for highly accurate systems, especially for safety and service purposes. Position sensors are the type Baily International sees the largest requests for; this is not surprising given the rising development and use of machine control systems and automation – knowing the position of a machine or one of its parts helps to ensure safe and optimal movements.

Bankhead of Hydraforce/Rexroth said there is a trend toward integration of digital electronic technologies such as hydraulic controls with onboard electronics and integrated sensing. "The integration of sensors is a critical path to adding value to the market with digitally connected hydraulics," he said.

Herrin said the discussion of electronic control systems taking the place of mechanical controls has been taking place for years. "I can remember when electronically actuated hydraulics made up 5 or 7% of the market. Now we're well above 50%," he said. "The use of electronic controls is a long-term trend that will continue. A key reason is that OEMs want to differentiate and customize their solutions, and that is almost always done with software today. Hydraulic components have to be electronically actuated to work with these custom solutions."

Childers noted the move toward Industry 4.0 as a driver for the greater integration of

electronics as well. In addition to integrating sensors, portals and communication networks enable collection and monitoring of collected data to ensure productivity of a system or machine. She said Parker offers a solution with built-in diagnostics capabilities which helps to detect short circuits in valves and monitor valve cycles, aiding with maintenance of the pneumatics system.

As electronics become more integrated with hydraulics and pneumatics, there will likely be more of a hybridization of these systems. The vast majority of survey respondents, 98%, said they see the trend of systems becoming a hybrid of electronic and mechanical technologies increasing further in the coming years.

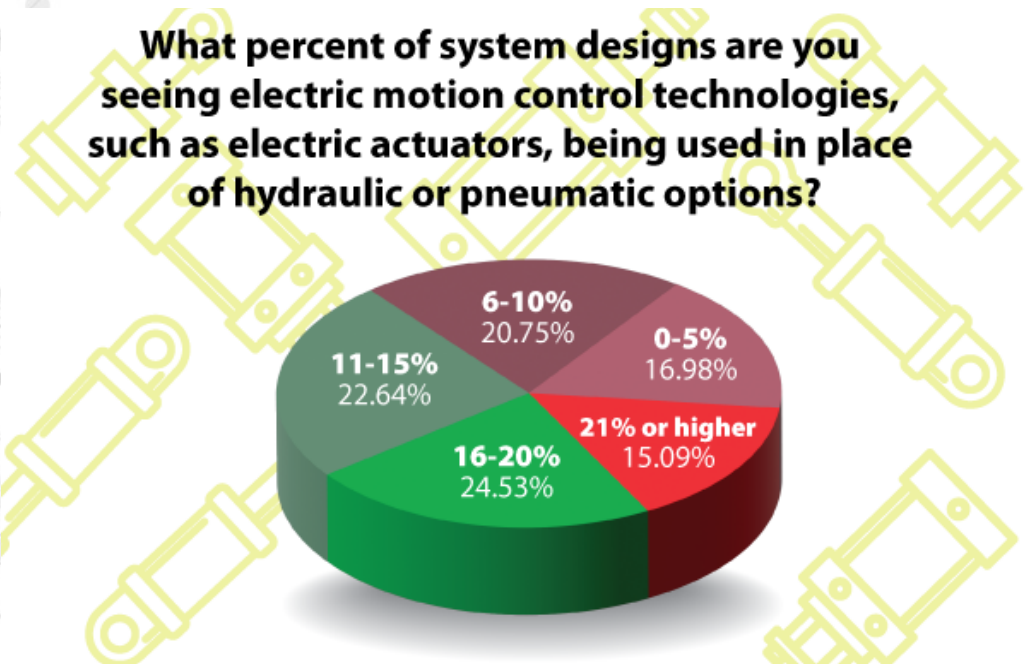
Market Share for Electric Actuators Increasing

In addition to electronics being incorporated with hydraulic and pneumatic technologies, there are increasing instances of electric actuators and other technologies being used in place of fluid power options. Most survey respondents indicated they see this trend, and were fairly evenly split between how much they see electric options being used in place of fluid power technologies.

Twenty-four percent said they see as much as 16-20% of system designs using electric motion control technologies in place of hydraulic or pneumatic options. Just 15% said they see 21% or more of systems using electric alternatives – indicating this is a growing trend but there remains space for hydraulic and pneumatic technologies.

When asked if they see electric options ever fully displacing hydraulics or pneumatics, the majority of survey respondents said they do not see this happening. Several noted the fact that the power density of hydraulics in particular cannot be beat. Others said there will always be applications which require the use of hydraulics or pneumatics.

Automation and the positioning accuracy and repeatability possible with electric actuators for robotics were some of the reasons given by those who see the use of electric options increasing.



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Andrew Zaske, Vice President of Sales and Marketing at Tolomatic, said the increasing demands of uptime, repeatability and reduced maintenance are among the reasons people are moving toward use of electric actuators. He also said the company is seeing growing interest in using electric actuators in place of hydraulics in new areas.

Tom Diedrichs, Product Manager Actuators at Ewellix, sees this trend occurring as well. "There is a general push for hydraulic replacement in all types of applications that see value in the benefits that electromechanical actuators [aka electric actuators] bring," he said which includes efficiency, energy use and better position accuracy.

Another benefit he points to is safety – with electric actuators there is no chance of hydraulic fluid leaking and causing harm to humans or the environment. In addition, because there are no fluids working under high pressures, safety issues are mitigated when maintaining systems.

When determining whether to use a fluid power or electric motion control solution, it is important to evaluate the application and performance requirements as well as component and system costs and productivity gains said Bateman.

As Moog Inc. stated to *Power & Motion*, "In today's world, it is critical to understand that power and motion control is a shared space between fluid power and electric technologies. For example, Moog Construction collaborates with OEMs on their power, motion, and sustainability efforts by looking at the crossroads of hydraulics and electric power technologies. In the case of a tractor loader backhoe or excavator, a manufacturer might want to have a vehicle's wheels or tracks powered by an electric motor while the machine's working hydraulics would employ hydraulic actuators powered by an electric motor and battery system.

"Determining what's best for an application will, in Moog's opinion, continue to guide technology selection and innovation with hydraulic, hybrid, and fully electric power and motion control solutions."

Overall, a positive sentiment remains for the fluid power industry even as electric options are becoming more common. Most survey respondents, 58%, foresee the hydraulics and pneumatics market performing somewhat positively over the next 5 years, and 26% see it performing very positively.

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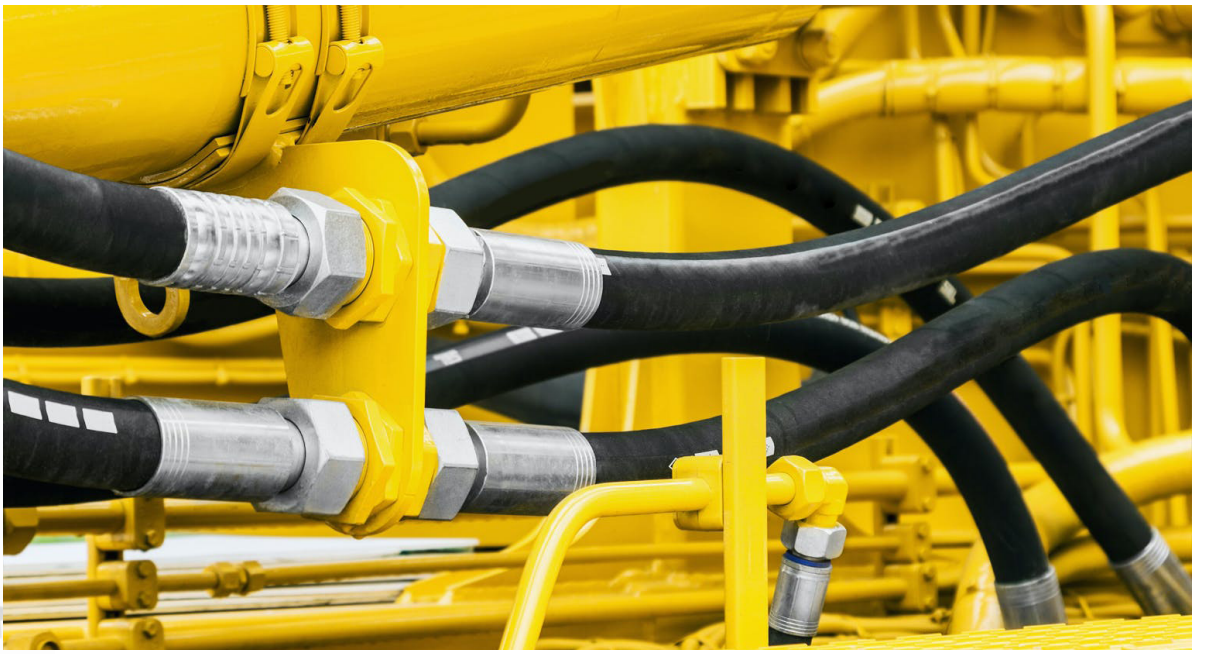


Oleg Doroshin | Dreamstime.com

CHAPTER 2:

2024 Recession Presents Fluid Power Industry Opportunities for Investment

SARA JENSEN, Technical Editor, *Power & Motion*

With a mild recession predicted for 2024, fluid power manufacturers should use this time to invest in their business and prepare for the rebound coming in the second half of the decade.

After months of predictions about a potential recession in 2024 for the fluid power industry, and broader U.S. and global economies, the data shows this will in fact be the case.

The data indicates total shipments for fluid power products have tentatively peaked and are facing decline in the year ahead, said Patrick Luce of ITR Economics during the National Fluid Power Association's (NFPA) Fall 2023 Economic Update webinar. He noted there are some headwinds in place which have the potential to cause downside pressures to linger into early 2025.

Declining profits, stricter lending criteria and overall elevated interest rates are creating tougher financial conditions for businesses. Because of this economic evidence, Luce said ITR expects contraction in a wide array of fluid power end markets. The current expectation is a nearly 10.9% contraction in 2024 compared to 2023.

However, those in the hydraulics and pneumatics industry should think of 2024 as an opportunity year he said. Companies should invest in their business to not only get ready for the nearly 10% year-over-year growth expected in 2025 but also take advantage of the reductions in pricing that will occur in 2024. A mild decline is expected for the producer price index throughout the year, offering good buy-low opportunities.

In addition, a light dip is expected for the interest rate environment in late 2024 and early 2025 which will benefit both the overall economy and businesses looking to make capital investments.

Hydraulic and Pneumatic Shipments to Decline in 2024

Both segments of the fluid power industry are expected to experience a downward trajectory in 2024 before seeing growth again in 2025. Looking at the broader forces within the industry, the data trends move in sync with one another, said Luce. The cyclical momentum hydraulics and pneumatics have experienced since 2020 is beginning to wain and a dip in overall activity is starting. This dip will continue into late 2024 and early 2025 at a variety of paces.

ITR is forecasting hydraulic shipments in 2023 to be up 6.3% compared to 2022 but down about 11% in 2024 before rebounding in 2025 when growth is currently forecast to be up 9.1%. Key end markets for this segment of the industry – including agriculture, mining and construction equipment – are facing downside pressures due to the tougher financial conditions these sectors, like many others, are experiencing, said Luce.

Softening in the overall economy is presenting headwinds for the agricultural and mining equipment markets, both of which are already declining, although he noted the oil and gas segment is an outlier. This portion of the mining industry is showing some resilience and rising at a steady pace. It is expected to only experience a mild decline in 2024 and therefore could be an area of opportunity for hydraulics manufacturers.

Pneumatics shipments should end 2023 up about 5.3% compared to 2022 based on recently revised data from ITR, said Luce. In 2024, this segment of the fluid power industry is expected to be down 5.9% compared to 2023 but rebound to growth of 2.9% in 2025.

Early to mid-2024 is when the pullback in pneumatic shipments is primarily expected, he said. This is due in part to declines in the manufacturing sector – a key customer market for pneumatic components and systems.

READ MORE: Growth Potential Ahead for Hydraulic Fittings Market

The agricultural equipment market is among the mobile machinery sectors facing headwinds from the slowing global economy. Steve Allen | Dreamstime.com

Focus on Positive Markets for Fluid Power

Given the forecasted slower growth trends, it will be important for companies working in the fluid power space to strategize into the market winners in 2024, said Luce.

He said companies should be planning now and have contingency plans in place for both upside and downside risks which could occur in 2024. Some of the leading indicators show an economic recovery could happen sooner, presenting a possible upside risk for which businesses will want to be prepared. Potential downside risks to account for include waning profitability and higher interest rates.

While planning for 2024 and beyond, he said companies should think about previous economic booms and what they wish they had done differently during the downturn to set their business up for success. Using this information can help better time actions to take so a business can capitalize on and be ready for the rise in economic conditions anticipated in 2025 and much of the second half of the decade.

Companies should look for ways to lean into their competitive advantages while also taking the time to address any possible competitive disadvantages it has in its marketplace. Identify, recognize and address them, said Luce. The slower economy provides an opportunity to invest in system upgrades and efficiency improvements. Anything a company can do now to abate current labor challenges will better set it up for success during the last half of the decade.

Manufacturing Production Offers Insights into Opportunity Areas

The U.S. Total Manufacturing Production Index has been in decline through much of 2023 and expected to remain so into 2024. However, it will already be in a state of recov-

Pneumatic shipments are forecast to primarily be lower in the first half of 2024 before picking up again as the various sectors it serves, particularly manufacturing, start to recover later in the year. Srki66 | Dreamstime.com

ery by the end of 2024 and into 2025. Luce explained that ITR does not define recovery as a market experiencing growth but instead as the rates of change becoming less negative.

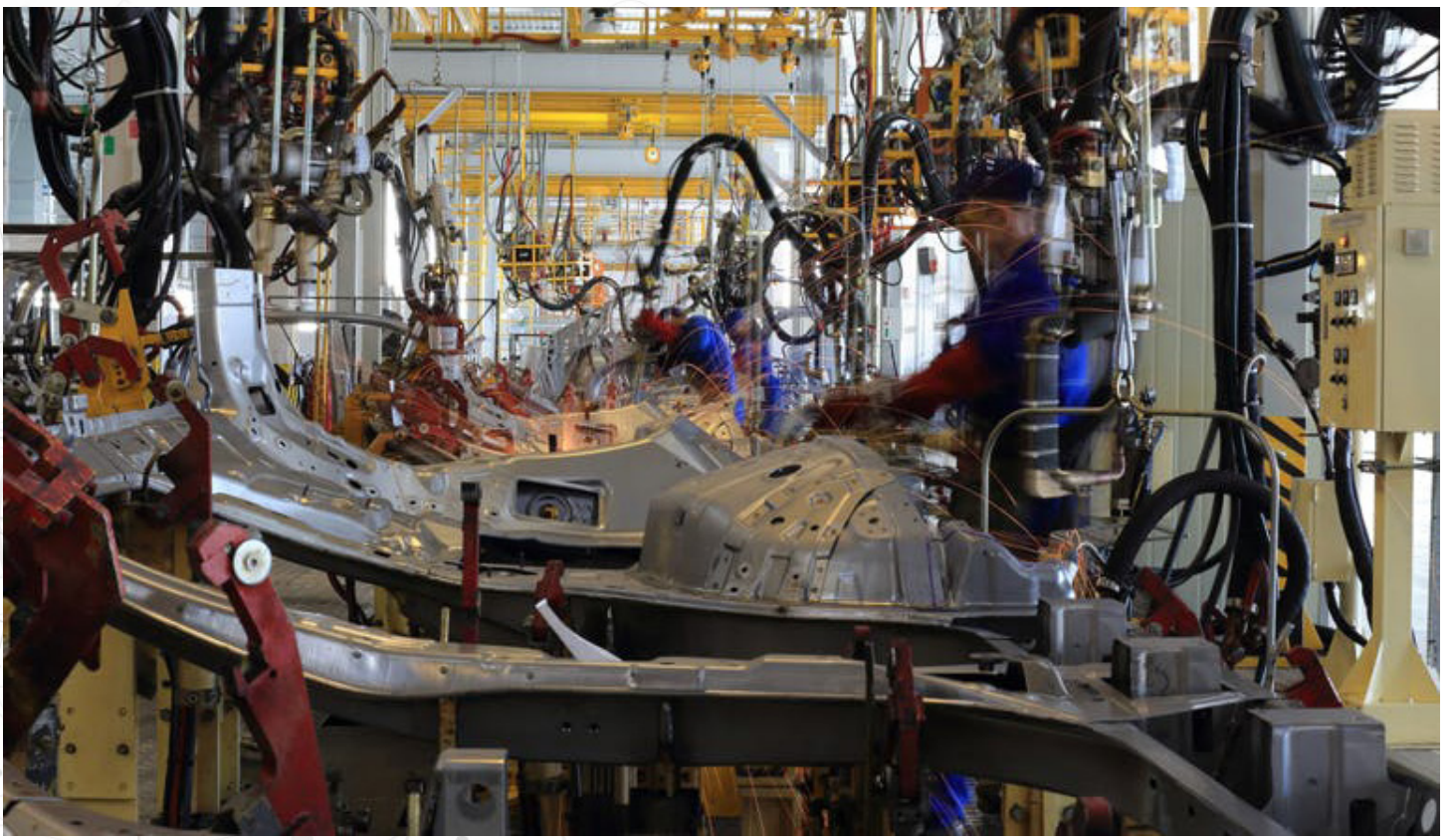
By year-end 2024, manufacturing production rates of change will be getting less negative, he said, and gearing up for growth in 2025.

Besides looking at this broader macroeconomic trend, he said examining where manufacturing output is most robust is beneficial as well by targeting regionally specific opportunities. The best way to ride out a recession is to gain market share, whether in vertical markets or exploring new ones.

As manufacturing production enters recovery, there may be market regions – like the Midwest – where that sector plays a greater role in overall GDP and therefore could be an opportunity area to explore.

Related to this, Luce said there is a lot of new money coming into the U.S. to propel new spending in the economy for more production due to reshoring efforts as well as foreign direct investment. Monitoring these activities could provide fluid power manufacturers with potential new business opportunities. Investments in electrification, including battery production, and chemicals are strong sectors from a reshoring standpoint.

Fluid power companies should also re-evaluate their product offerings and end markets. It is important to place an emphasis on the products and services which tend to do well during periods of contraction, said Luce. These typically include those capable of improving a customer's return on investment. As such, a company's marketing and other aspects should be focused on how they can offer a competitive advantage in this area.



Companies should look to the regions where manufacturing is strongest as they may provide economic opportunities when the sector enters a recovery phase toward the end of 2024. Anastasiyaanastasiya | Dreamstime.com

He said now is also the time to evaluate any unprofitable business segments. If there are ones which are having trouble making profits in 2023, they will likely have more trouble doing so in 2024 and therefore a company should de-emphasize investments in these segments. Reallocate time and investment into more profitable market segments to help maintain overall business health.

Potential in Maintenance Services

According to Luce, services have been holding up better than the overall economy and spending on durable goods. The rates of change for U.S. Commercial and Industrial Equipment Repair and Maintenance Services Revenue remain elevated.

As such, this an area the fluid power industry could evaluate as a potential avenue for new revenue streams either by providing services or offering solutions for those in the service industry. The service and repair space is not necessarily recession proof but recession resilient, said Luce, and therefore an area of opportunity during these economic periods.

The rates of change look to remain elevated in the foreseeable future for this space, making it one for those in the hydraulics and pneumatics industry to consider while making marketing and strategy plans for the coming year.

READ MORE: Pneumatics Continue to Adapt to Market Needs

How Broader Macroeconomic Trends Could Impact Hydraulics and Pneumatics

There are several trends happening in the broader macroeconomy which could influence the fluid power industry and its customer markets in the coming year.

Third quarter 2023 U.S. GDP (gross domestic product) figures were generally positive, said Luce, and slightly above expectations. The U.S. economy grew during the quarter and record high levels were achieved for real GDP.

However, he said there are some cracks showing in the economy's general trends. Consumers continued to spend in the third quarter, but delinquency rates are starting to rise, an indication financial weakness is beginning for consumers.

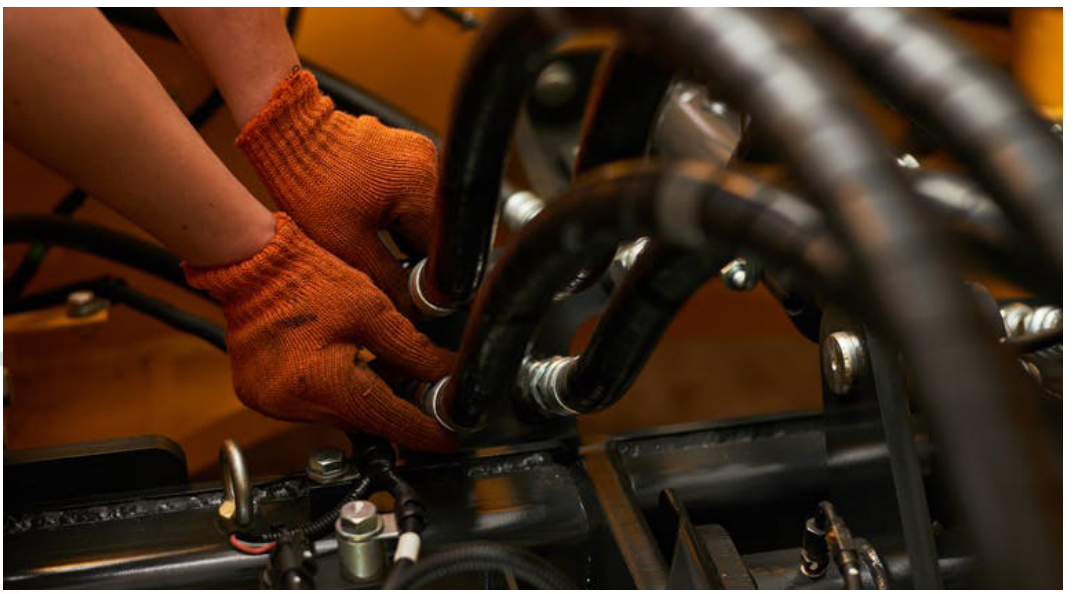
The ability of consumers and businesses to weather the higher interest rate environment

What is a recession?

Patrick Luce of ITR Economics said there are two ways to define a recession. The first is the technical definition which is when there are two consecutive quarters of GDP (gross domestic product) decline.

He said ITR is not forecasting there to be two consecutive quarters of GDP decline in 2024. Instead, it will be a little bouncy – so quarter one down, quarter two up, quarter three down and quarter four up – and have a generally flat trend. Ultimately, GDP will not enter into a technical definition of a recession.

The more formalized definition from the National Bureau of Economic Research says a recession occurs when there are decreases in overall employment and overall output and industrial production. Luce said ITR does see recession in these terms occurring in 2024, and it has already begun.



Maintenance and repair is a relatively recession resistant sector, making it a potential opportunity area for hydraulics and pneumatics manufacturers. Denys Yelmanov | Dreamstime.com

may be dwindling as indicated by the supply of money in the economy drying up and weakening credit conditions. The latter could make it more difficult to get loans and is a key factor for the recessionary headwinds ITR sees, said Luce.

How the Federal Reserve interprets the third quarter GDP figures could determine when the economic recovery begins, said Luce. The Federal Reserve could see the strong performance as a reason to keep interest rates at higher levels for a longer period of time which could delay the start of the 2025 rebound.

When digging deeper into what drove third quarter GDP growth, he said personal consumption expenditures for household services was the number one driver. Utilities are included in this and take away from spending on other activities, especially durable goods. The pace of growth for goods was smaller and most resided in the automotive sector, he said, which is not expected to be as robust going forward because much of the pent-up demand and supply chain pressures from the last few years are abating.

Government spending – at local, state and federal levels – was also a strong contributor to GDP growth in the third quarter. Luce said this could be an opportunity area for the fluid power industry. All levels of government are still spending money as well as adding staff, making it one of the stronger market sectors currently. The Infrastructure Bill, CHIPS and Science Act and Inflation Reduction Act are all helping put money into the economy and providing good opportunities for domestic production with a lot of reshoring activities occurring as a result.

Take Precaution with Inventory Levels

One GDP growth factor which particularly stood out to Luce – and was the second largest contributing factor to third quarter growth – was the fact increases in non-farm inventories were very elevated. Increases in inventory can add to the overall GDP level but are not necessarily a signal of economic health, he explained. Companies which have

Watch our interview with Eric Alstrom, president of Danfoss Power Solutions, to hear how he believes the Infrastructure Bill will benefit the fluid power industry.

rapid rises in their inventories must typically pull back on business investment so they can rebalance their inventories.

Inventories are likely going to pose challenges for the economy going forward and many companies are already feeling the effects of the current imbalance as demonstrated by business investments currently being down from year-ago levels.

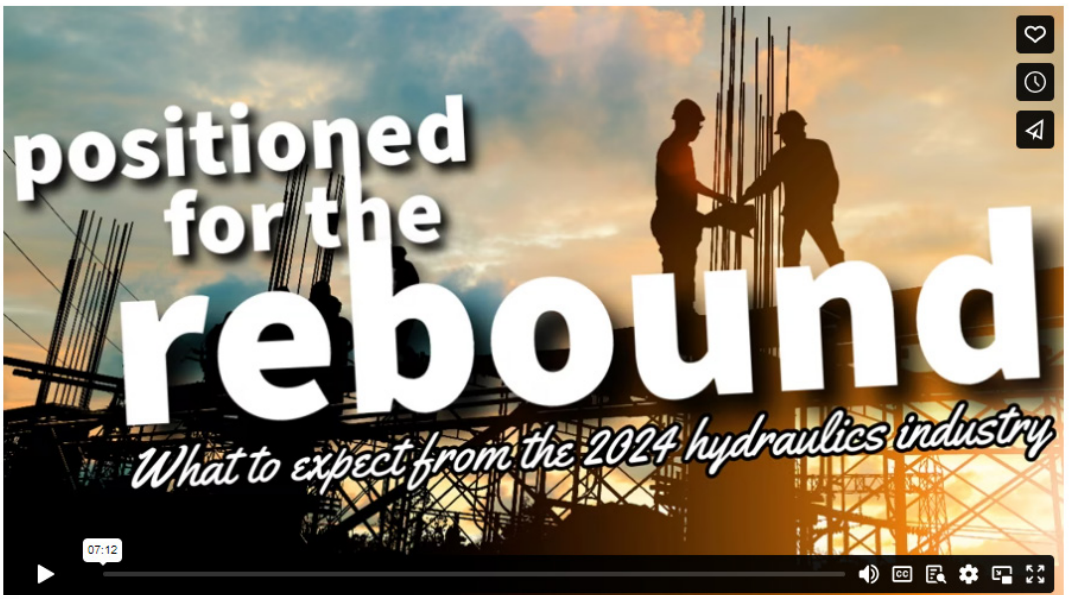
Luce said a key trend to monitor is inventory levels and that it is normal for the U.S. economy to overbuild inventories when transitioning from growth to contraction. This happens because the inventory turnover ratio falls and companies want to compensate, which is a normal cyclical relationship.

However, the COVID-19 pandemic exacerbated this because of the challenges many businesses were facing. There was an elevated lead time situation due to global supply chain pressures compounded by a surge of stimulus spending and demand, he said. This created a lot of upside pressure on lead times, causing businesses to buy forward on their inventory to keep up.

As supply chain pressure and demand began to slow, there has been a surge of inventory throughout the last half of 2022 and into 2023. Over the next 12 months ITR expects a rebalancing of inventories. Businesses will sell off their existing inventories and not necessarily build them up or grow them, said Luce.

This could provide opportunities for those in the fluid power industry. As businesses look to offload their inventories, hydraulics and pneumatics manufacturers could take advantage by locking in contracts and stocking up their own inventories in the later half of the year in preparation for the growth anticipated in 2025. Typically, he said the economy lags in inventory planning, but this could be a chance for fluid power manufacturers to plan ahead and have the capacity to meet demand as it picks up again after 2024.

Ken Baker, CEO of Bailey International, said in an interview with *Power & Motion* the company will be keeping a close eye on its inventory levels because it is important to find a good balance between not building up too much but being ready for the coming rebound.



Watch our interview with Ken Baker to hear how views the hydraulics market performing in 2024 and how the company will be preparing for future growth.

Key Economic Takeaways for the Fluid Power Industry

Although 2024 will be a recessionary year, it is expected to be a mild one – and nothing like what was experienced in 2008. The slowdown in economic activity will provide an opportunity for many businesses to breathe after the strong uptick which took place as the world emerged from the COVID-19 pandemic.

READ MORE: A "Good" Recession for Hydraulics and Pneumatics

With demand and the overall economy slowing, supply chain pressures have eased which is beneficial for many businesses as they spent much of the past few years trying to overcome this challenge. Current data indicates more normal supply chains are likely over the next 7 months.

Related to this, nearshoring and reshoring efforts are creating shorter supply chain networks that are both good for businesses as well as potential opportunity areas for many.

Luce said nationalism – bringing more production back to the U.S. and nearby regions – is the long-term play that will benefit economic growth going forward. While the country is facing an aging demographic, it is not nearly as pressured as most advanced nations like China and Europe.

Interest rates and various geopolitical events could present challenges, and should continue to be monitored.

But in general, 2024 should be seen as a year to invest in one's business and maximize competitive advantages to prepare for the growth anticipated in 2025 and beyond.

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THE STATE OF
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Alptraum | Dreamstime.com

CHAPTER 3:

Growth Potential Ahead for Hydraulic Fittings Market

SARA JENSEN, Technical Editor, *Power & Motion*

Positive market conditions for the hydraulics sector and its various customer markets will drive growth for hydraulic fittings in the coming years.

The global hydraulic fittings market is forecast to grow 5.4% through 2029 according to market research firm Valuates Reports. Its "Global Hydraulic Fittings Market Research Report 2023" expects the market to reach a value of U.S. $2110.1 million by 2029.

In 2022, the hydraulic fittings market achieved a value of U.S. $1,453.9 million. Growth for hydraulic fittings between the forecast years of 2023 to 2029 will be driven by strong demand for hydraulic systems in a range of applications, including automotive, construction machinery and manufacturing.

Valuates Reports says China accounts for 30% of market share while America is 27%. Growth in both markets is anticipated as investments in manufacturing facilities and infrastructure continue to rise and drive the need for hydraulic systems and thus the fittings they utilize.

The Importance of Hydraulic Fittings

Hydraulic fittings are a vital part of hydraulic systems, enabling a sealed connection between various components. As fittings can typically be removed, they make it easier to service systems when necessary.

Fittings are available in a range of materials and types to best suit the needs of various applications. The Valuates Reports research looks at the projected market performance for steel, brass, aluminum and plastic hydraulic fittings as well as their varied applications, including those which extend or terminate pipe lengths, add or change direction as well as fittings designed to connect pipes of smaller sizes and those providing special connections or functions.

READ MORE: Hydraulic Fittings and Flanges

Market demand for hydraulic fittings of various types will be positive through 2029 due to strong market conditions for the hydraulic systems in which they are used.

Mikita Kavaliou | Dreamstime.com

The power density and dependability of hydraulics remains unmatched in many applications, especially heavier duty ones, necessitating their continued use in industries such as construction, agriculture, aerospace, automotive and manufacturing.

Projected growth in the coming years for these industries will lead to strong demand for hydraulic systems and their various components such as hydraulic fittings.

Drivers for Market Growth

A range of market factors are anticipated to help drive growth for hydraulic systems, and therefore their various components such as hydraulic fittings, over the next several years.

According to Valuation Reports, creation of new, more environmentally friendly fitting designs will be among these which will be driven by developments in new technologies and materials, regulations promoting improved energy efficiency and efforts to make hydraulic systems and the applications into which they are integrated more sustainable.

Brad Rico, Vice President of Sales & Marketing at Brennan Industries, said diversification will be a strength for the company in the coming years, including its ability to supply alternative fitting solutions in brass, composite materials, malleable iron, steel, stainless steel, and exotic materials.

“Our ability to provide multiple solutions to the aerospace, automotive, marine, mining, power generation, pharmaceutical, agriculture, food and beverage industries will also aid our success,” he said. Serving customers in multiple countries around the world will benefit the company as well, with Europe, Canada and Mexico representing tremendous growth opportunities according to Rico.

In the aerospace and defense industries in particular, Valuation Reports states advanced fitting designs will be required for years to come due to the safety and rugged environments associated with these sectors. Fittings and other hydraulic components must be dependable and long-lasting, necessitating continued development of improved

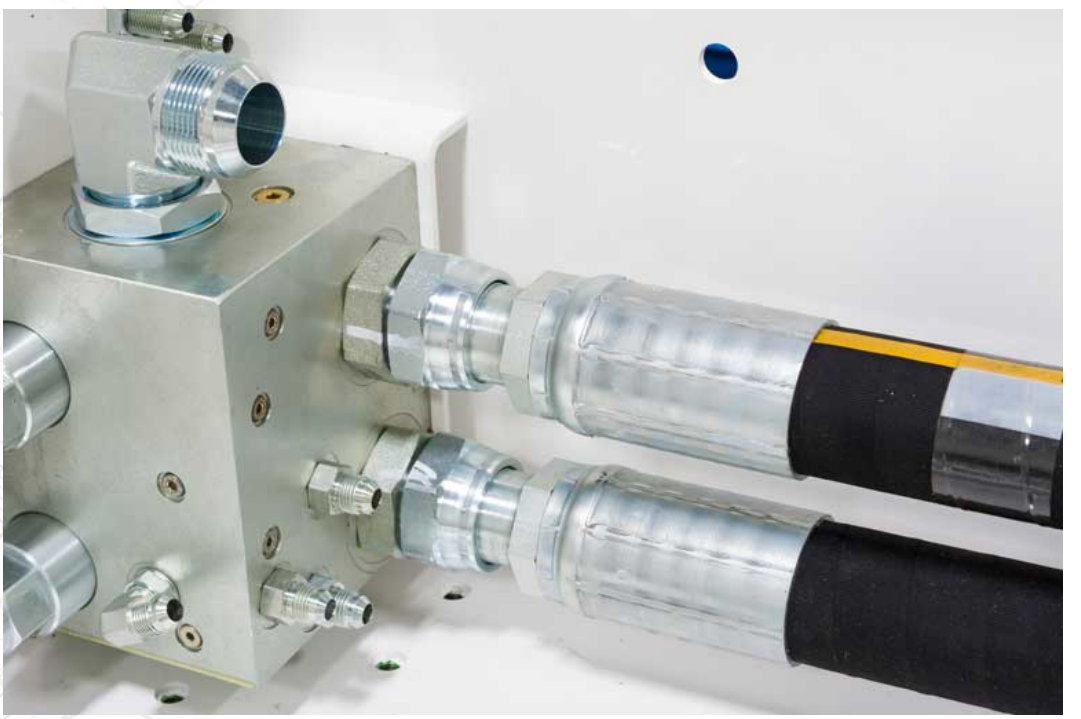
designs which will benefit growth in the hydraulic fittings market.

READ MORE: The Vital Role of Hydraulic Systems in Aircraft

The research firm says worldwide efforts to industrialize and automate various processes are driving growth for the hydraulics, and thus the hydraulic fittings, market. For instance, many parts of the world are increasing their use of mechanized agricultural equipment – one of the top customer markets for hydraulics – to help make planting and harvesting of crops more productive and efficient. Even as these machines and their various systems become more automated to further increase productivity and overcome labor challenges, hydraulics will remain necessary as they drive many of the work functions of agricultural and other heavy equipment.

The Freedonia Group is projecting global demand for agricultural equipment to increase 6.5% each year through 2026 due in part to farmers replacing older machinery and regions such as China investing in further mechanization. Recent data from the Association of Equipment Manufacturers (AEM) shows larger tractor sales remain positive in the U.S. as farmers continue investing in new equipment and technology to help them reduce their production costs while increasing crop yields.

"The appeal of the newer equipment centers on improved fuel efficiency, better GPS technology, and improved automation features, which is why farmers are continuing to make these investments," said Curt Blades, senior vice president, industry sectors and product leadership at AEM, in the association's press release announcing its August 2023 farm tractor data.



Hydraulic fittings connect and seal other components within a hydraulic system, making them a vital component with long-term growth opportunities in the coming years. Scruggelgreen | Dreamstime.com

Investments in infrastructure projects around the world are benefiting the hydraulic fittings market as well. Use of construction equipment and other heavy machinery which rely heavily on hydraulic systems are building the roads, bridges and other structures for which funds are being provided – through government policies such as the Infrastructure Bill in the U.S. As such, demand for this equipment and the components within them is expected to remain positive as these investments continue over the next several years to improve older infrastructure as well as add it in regions where it may not have existed previously.

Related to this are the investments being made in new manufacturing facilities as part of near- and re-shoring efforts. Hydraulics play an important role not only in the equipment building these facilities but also in the manufacturing operations themselves as they are utilized in various production machinery as well.

READ MORE: How the CHIPS and Science Act Will Benefit Fluid Power and Motion Control Manufacturers

Valuates Reports also points to the automotive industry being an important growth driver for the hydraulic fittings market. Hydraulics continue to play a role in the steering and braking systems of many on-road vehicles, and this industry has picked up steam again as consumer interest has renewed after many postponed purchases when the global pandemic hit in 2020. In addition, the semiconductor chip shortages which previously plagued it has begun to subside, better enabling car manufacturers to meet demand.

Another area of growth Valuates Reports sees is renewable energy. The research firm notes hydraulic systems are important components within wind turbines and solar tracking systems. With global efforts increasing to utilize these and other alternative power systems to reduce carbon emissions, long-term growth is anticipated for hydraulic systems, and thus fittings, used in this sector.

Sustainability Presents Challenges and Opportunities

Brennan's Rico said electrification and continued replacement of fossil fuels presents a threat to the marketplace. However, the ability to develop alternative solutions and serve multiple markets and industries will provide opportunities for growth in the coming years.

Valuates Reports sees renewable energy as an area of growth for the hydraulic fittings market. The research firm notes hydraulic systems are important components within wind turbines and solar tracking systems. With global efforts increasing to utilize these and other alternative power systems to reduce carbon emissions, long-term growth is anticipated for hydraulic systems, and thus fittings, used in this sector.

Joe Carr, Product Manager – Specialty Fittings at Brennan Industries, said many customers see DIN fittings as a good option for applications in emerging markets such as hydrogen and wind. In general, the company is seeing increased demand in the U.S. for fittings with international thread types such as BSP, JIS and metric because more international machinery is manufactured and maintained in the region.

When it comes to metric types, Carr said DIN 2353 compression fittings are of particular interest to customers for hardline applications, and are especially popular for railcar production, steel mills and marine repair operations.

Mark Mazzone, Director of Business Development at Brennan Industries, said one of the strongest opportunities for growth is in instrumentation fittings. "As the natural gas market

Wind turbines and other renewable energy technologies present a growth opportunity for the hydraulic fittings market. Ssuaphoto | Dreamstime.com

evolves, the need for tube fittings and instrumentation fittings to move the fuel or gas will increase," he said. "Hydrogen fuel cells, liquefied natural gas (LNG), and other related markets will continue to grow as the world transitions to renewable energy."

Aftermarket will Prove Beneficial

The need to maintain hydraulic systems will benefit the hydraulic fittings market as well. Many of the machines and vehicles in which hydraulic fittings are used are in service for years, sometimes a decade or more, which requires their hydraulic systems and components to perform as desired during that time.

Properly maintaining the equipment and systems helps to ensure longevity. But occasionally it will be necessary to replace components such as fittings, offering manufacturers of these parts growth opportunities in the aftermarket.

READ MORE: How to Safely Maintain Hydraulic Systems

Today many machine and vehicle OEMs are working to extend the lifespan of their products to help customers reduce costs and improve sustainability – the longer products are in the market, the less material that winds up in landfills as well as inputs and energy used to manufacture them. Being able to easily replace some parts, like hydraulic fittings, will aid these efforts and provide long-term growth potential for the hydraulics sector.

In general, the global hydraulic fittings market will be an area of growth as demand for hydraulic systems and the applications in which they are utilized experience positive conditions over the next several years.

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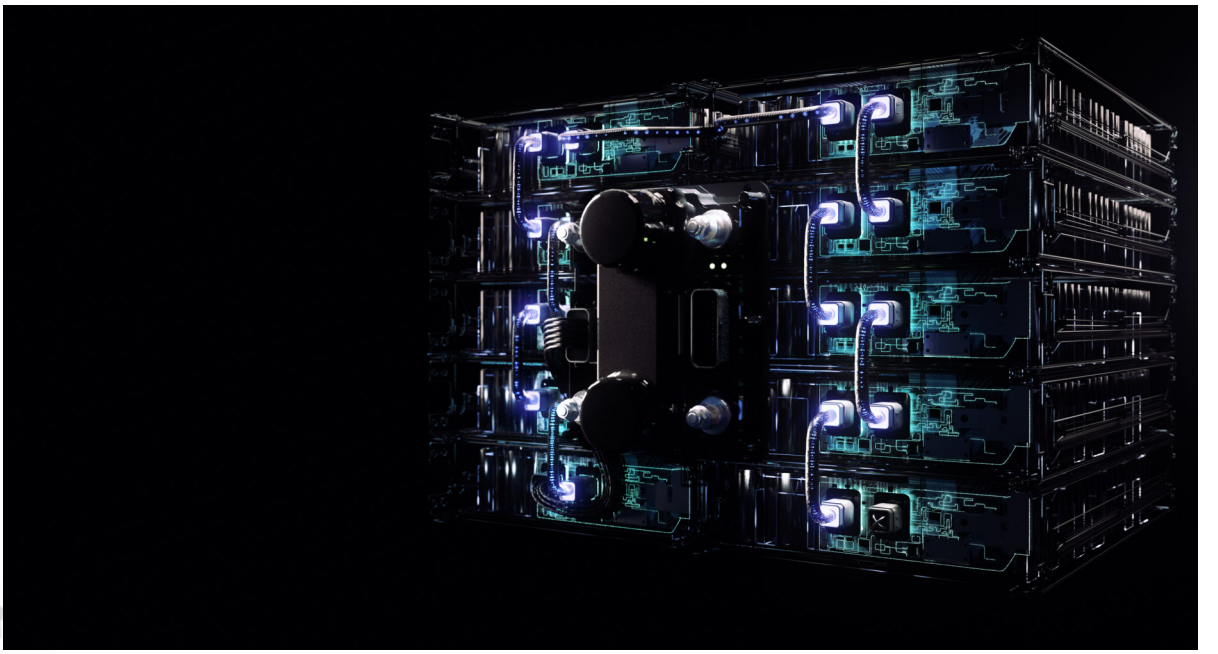


Yanmar

CHAPTER 4:

The Current State of Battery Technology

SARA JENSEN, Technical Editor, *Power & Motion*

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

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.

READ MORE: How is Electrification Impacting Hydraulics and Pneumatics?

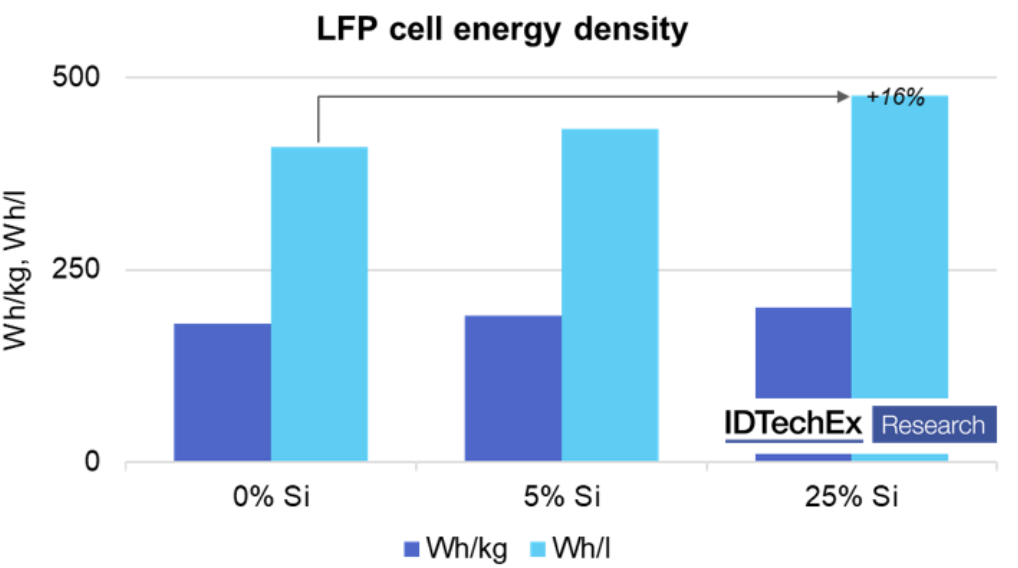
Common Battery Types

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.

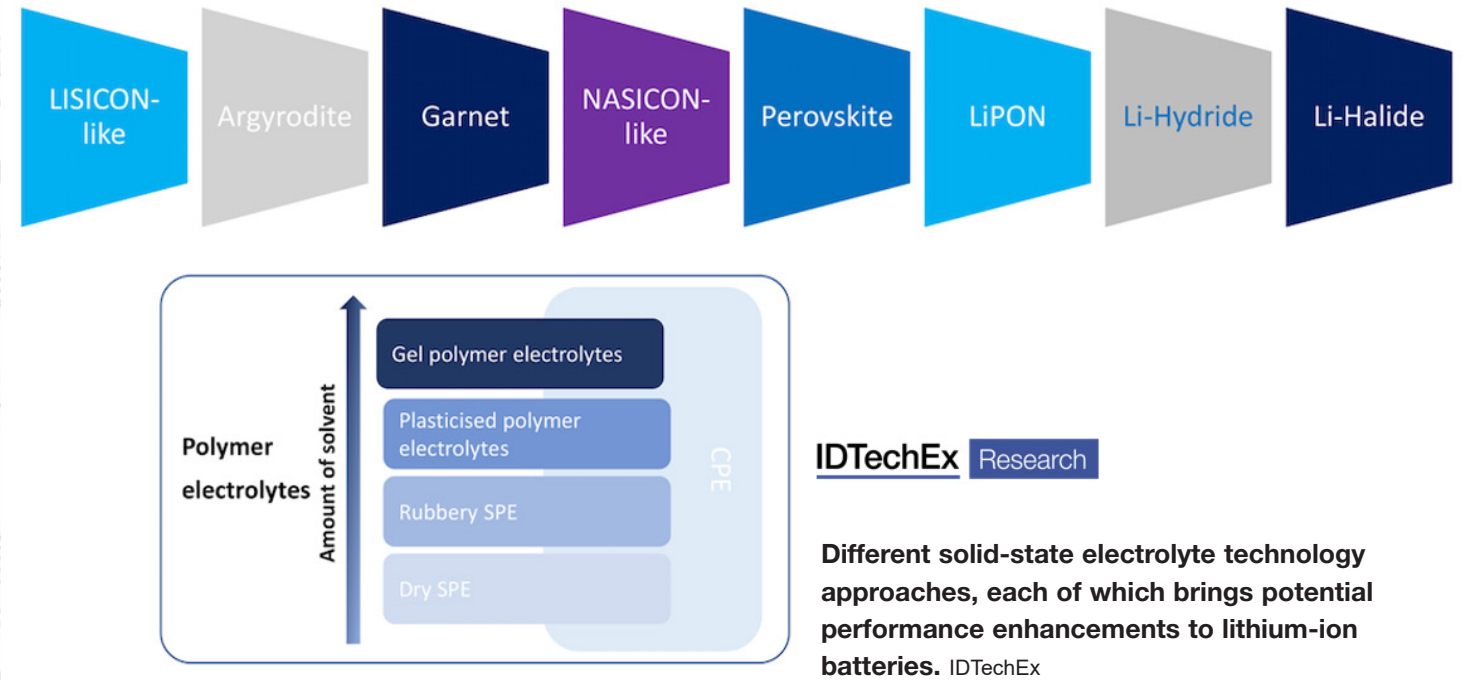
While lithium-ion has its benefits, it also presents challenges. According to research firm IDTechEx, the current versions of lithium-ion may be reaching their performance limits but new developments in cell materials and battery designs could help overcome these.

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.

The latest version of the Mack LR Electric is powered by NMC lithium-ion batteries offering 42% more energy and 376 kWh total battery capacity. Mack Trucks



Use of silicon can lead to large improvements in energy density for lithium-ion batteries. IDTechEx



Different solid-state electrolyte technology approaches, each of which brings potential performance enhancements to lithium-ion batteries. IDTechEx

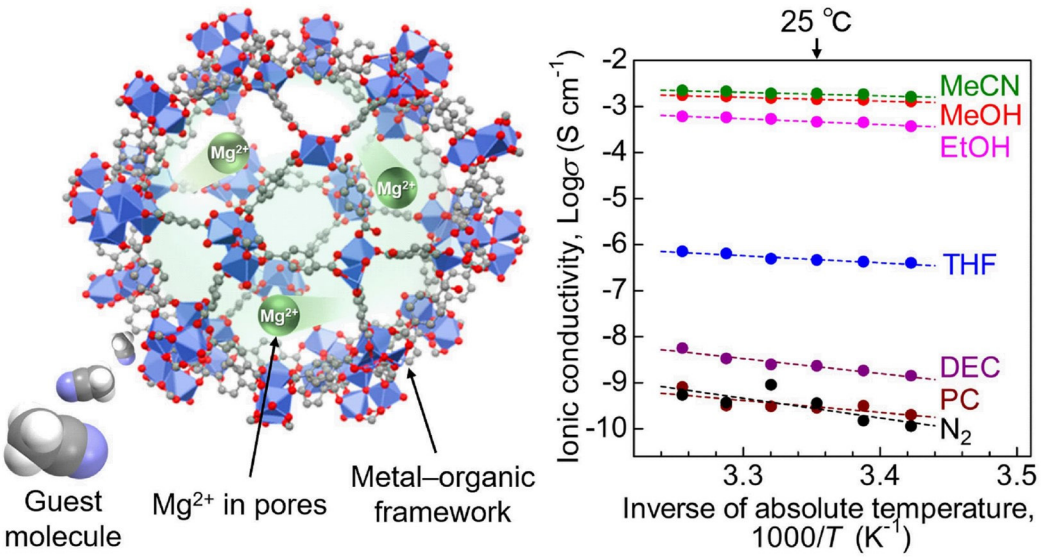
Use of new additives and electrolyte formulations is another way IDTechEx sees improvements to lithium-ion batteries being achieved. It noted one company which is utilizing phosphazenes and phosphorous-nitrogen compounds to help improve safety and performance.

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.



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 Sadakiyo from Tokyo University of Science

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.

READ MORE: Construction Equipment Digs Deeper into Electrification

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.

John Deere's acquisition of Kreisel Electric will help to bring its battery technology to a range of off-road equipment markets. John Deere

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. 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.

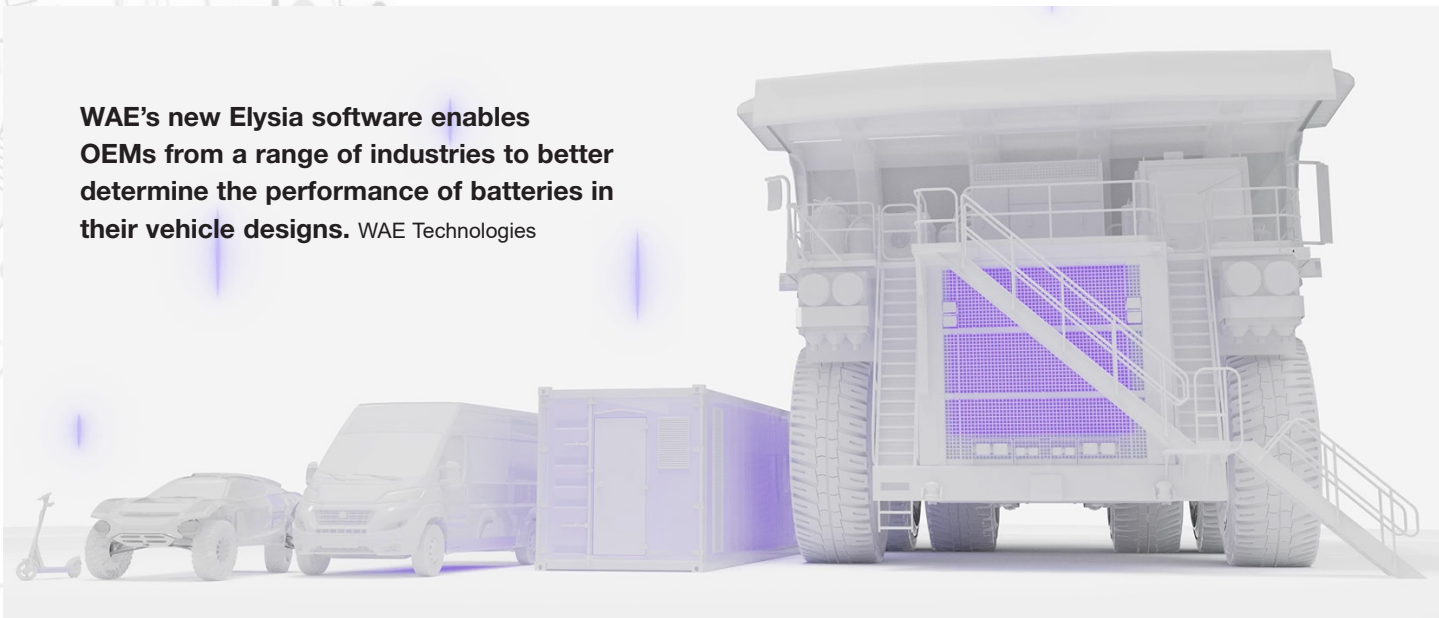
READ MORE: How to Safely Work with High-Voltage Systems

The modular design of ELEO's new battery system enables implementation in a range of heavy equipment applications. Yanmar

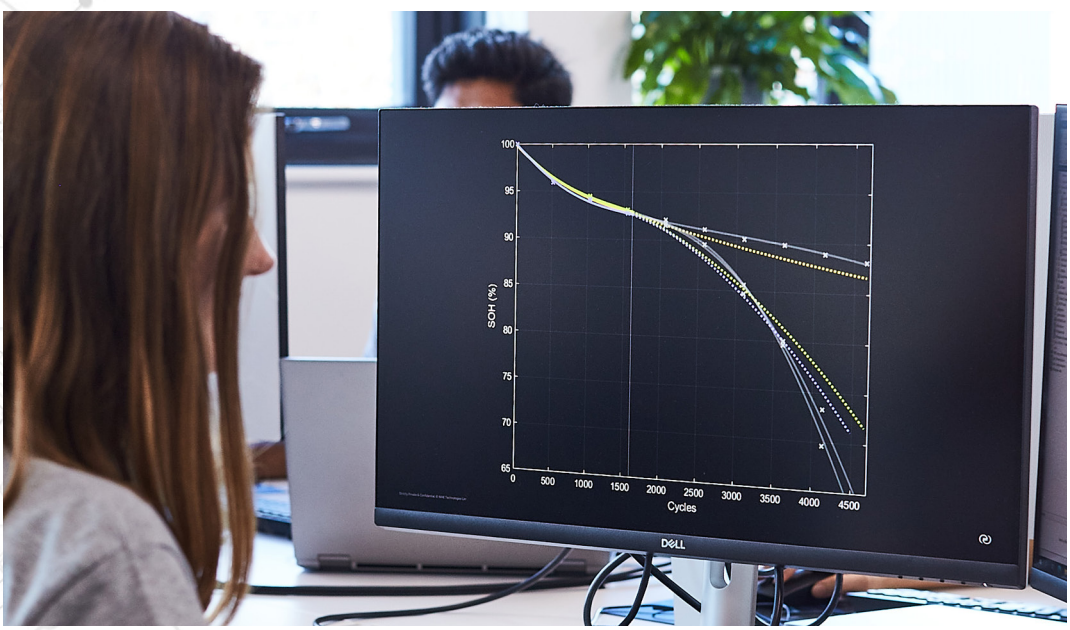
Performance Insights Benefit Design

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 as well as maximize battery power



WAE's new Elysia software enables OEMs from a range of industries to better determine the performance of batteries in their vehicle designs. WAE Technologies



A complete picture of a battery's state of health can be viewed within the Elysia Cloud Platform dashboard. WAE Technologies

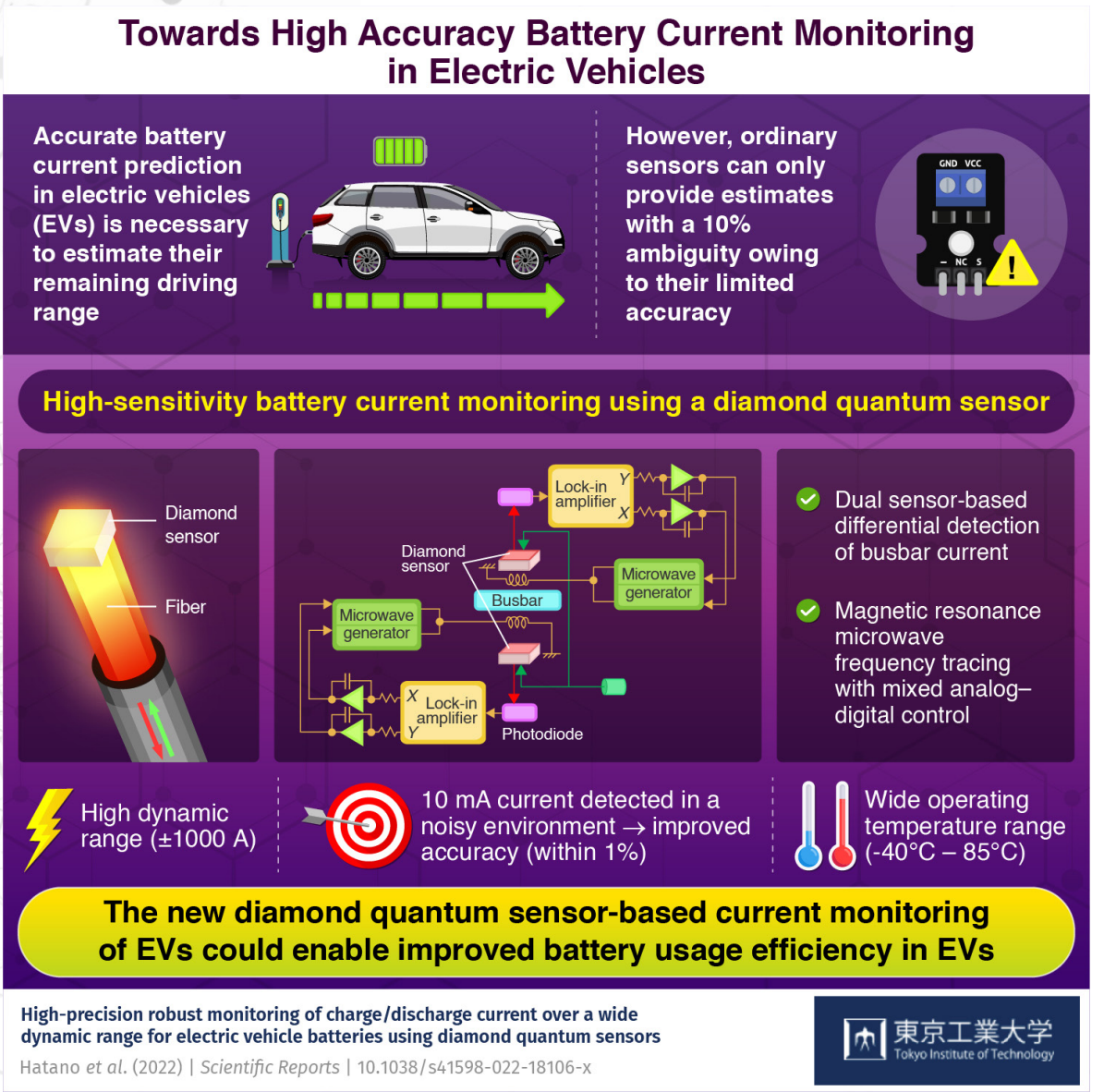
states WAE in its press release announcing the launch of the software.

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

READ MORE from Fleet Maintenance, an Endeavor Business Media partner site: Building brainier batteries

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



This infographic outlines the benefits of improving battery efficiency and how this can be achieved by using a more accurate sensor to detect battery charge.
Tokyo Institute of Technology

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 milliampere 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 milliampere 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.

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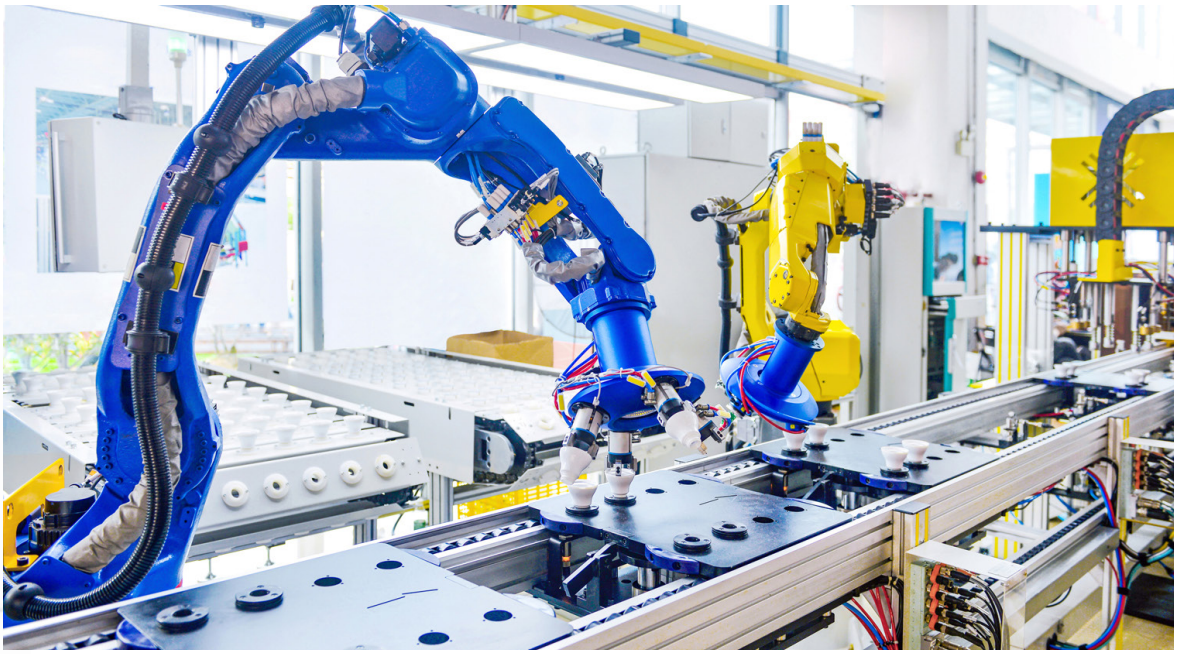


Photomall | Dreamstime.com

CHAPTER 5:

Steady Growth Expected for Motion Controls Market

SARA JENSEN, Technical Editor, *Power & Motion*

Investments in automation and new application uses will drive growth for the motion controls market in the coming years.

The global motion controls market is expected to be worth $18.9 billion in 2023 according to the latest data from research firm Interact Analysis. This will be an increase from the $17.7 billion the market was worth in 2022.

Steady growth is anticipated for the motion controls industry going forward after the high demand experienced in 2021/2022 due to strong demand from the consumer products sector which drove increased investment in automation – a prime user of many motion controls technologies.

While the Asia-Pacific (APAC) region is the largest market for motion controls, Interact Analysis reports the Americas will bring the highest levels of growth in 2023 at 7.4%.

The research firm is predicting a decline in global growth of motion controls in 2024 but a return to steady growth levels in the mid- and long-term.

Key Drivers for Motion Control Market Growth

Continued investments in automation from the manufacturing sector will help drive growth for the motion controls market. Motion control is a key element of automation by bringing together components to enable controlled movement, leading to improved productivity and efficiency (see sidebar below).

In its motion controls market report, Interact Analysis notes that in 2022 the APAC region, particularly China, was the largest for the sector, accounting for 37% of global revenues, followed by Europe, the Middle East and Africa (EMEA) at 33%. Japan accounted for 16% of the global market and the Americas 14%.

The Americas should see a greater share of the global revenues in 2023 as investments in manufacturing remain high in the region due to re- and nearshoring efforts — which includes the building of new facilities as well as integration of more advanced technologies such as automation.

Motion control systems provide controlled movement of machine parts, enabling improved precision and thus productivity and efficiency. Suwin Puengsamrong | Dreamstime.com

Semiconductors and electronics, which are large markets for use of motion controls, will benefit from the CHIPS and Science Act in the U.S., said Interact Analysis and thus aid with the motion controls industry's continued strength in the region.

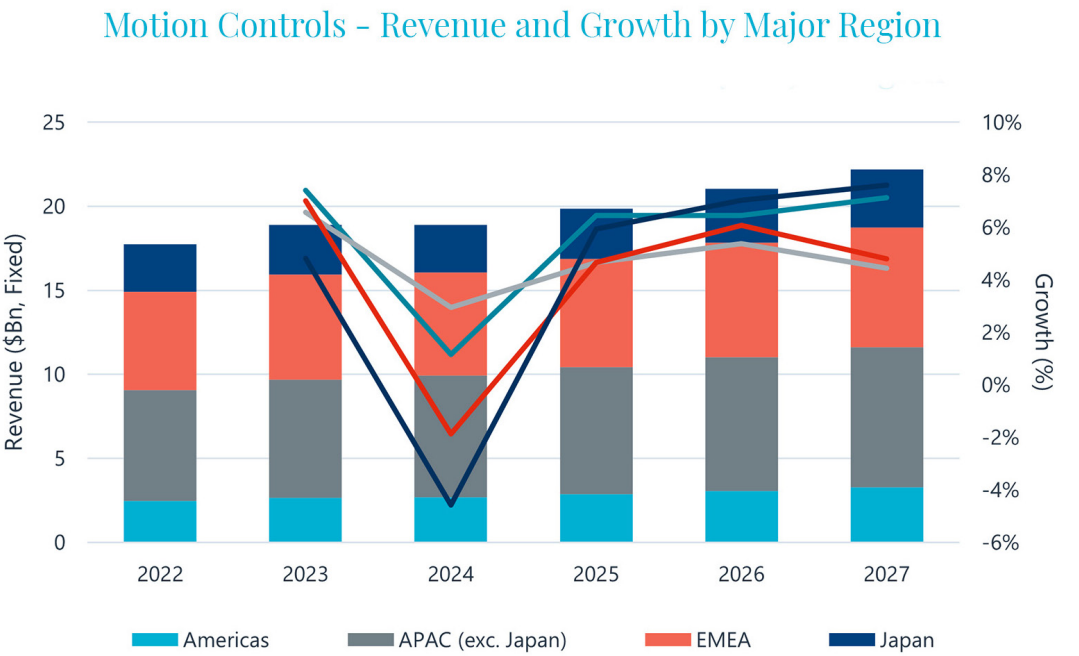
READ MORE: How the CHIPS and Science Act Will Benefit Fluid Power and Motion Control Manufacturers

In speaking with some vendors in the market, Interact Analysis said some are optimistic and anticipate growth rates as high as 20% in 2023. However, there are others who are less so and foresee a flat year compared to 2022.

High interest rates and inflation are factors somewhat mitigating investments in automation. The anticipated economic downturn predicted by ITR Economics and others in 2024 — a mild industrial sector downturn starting at the end of 2023 — is also factoring into some manufacturers' less than optimistic outlook.

Despite this slight downturn, overall the motion controls market is expected to see steady growth in the coming years. Investments in industrial automation will play a key role in this as the manufacturing sector looks to improve its productivity to meet ever increasing demand for products and overcome labor challenges.

Interact Analysis said the motion controls market will achieve a compound annual growth rate (CAGR) of 4.6% through 2027, reaching a value of $22.2 billion. Japan will likely see the largest drop in growth of all global regions during the 2024 economic turndown but then experience the strongest recovery with a growth rate of 6.9% through 2027.



The motion controls market is expected to see long-term growth through 2027.
Interact Analysis

Emerging Technology Areas for Motion Control Systems

While industrial machinery is a key segment for motion control technologies, their use in other applications is rising which should benefit further market growth in the coming years.

According to Interact Analysis, machine tools and semiconductor machinery makers are the largest users of motion controls with the metal cutting machinery sector accounting for the largest segment in 2021. Additional applications making use of motion control include packaging machinery, industrial robots and metal forming machinery.

These applications will continue to be strong use sectors for motion control, but as Interact Analysis reports, there is growing demand from other sectors as well. Mobile robots in particular have become a growth area for motion controls due in part to their need for precise motion and the rise in e-commerce increasing the need for more warehouse automation.

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Interact Analysis projects sales of motion control technologies into the mobile robot industry to achieve a CAGR of 52.0% through 2026. By that point, it predicts there being close to 1,000,000 mobile robots produced each year, leading to strong growth potential for motion controls.

Sales of motion controls to the textiles machinery industry will be the next largest application segment with a CAGR of 5.7% followed by the material handling equipment sector at 5.6%.

As use of motion controls grows in these and other markets, and efforts to implement automation in the manufacturing sector, continue, developers of these components should fair well in the coming years.

Automated mobile robots are a growth market for motion controls. Kittipong Jirasukhanont | Dreamstime.com

What is motion control?

Motion control is typically seen as a sub-field of automation and the movement of parts in a controlled manner.

As explained by A3 - Association for Advancing Automation, it is a term used to describe how individual components work together to create controlled movement within a machine. The three main components which comprise a motion control system include:

- controller
- motor drive
- motor which could be stepper or servo motors or linear actuators.

Sensors, cabling and other sub-components are included as well to ensure optimal machine part movements.

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