May/June 2023

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For Hydraulics and Pneumatics, Challenges and Opportunities Abound p. 10

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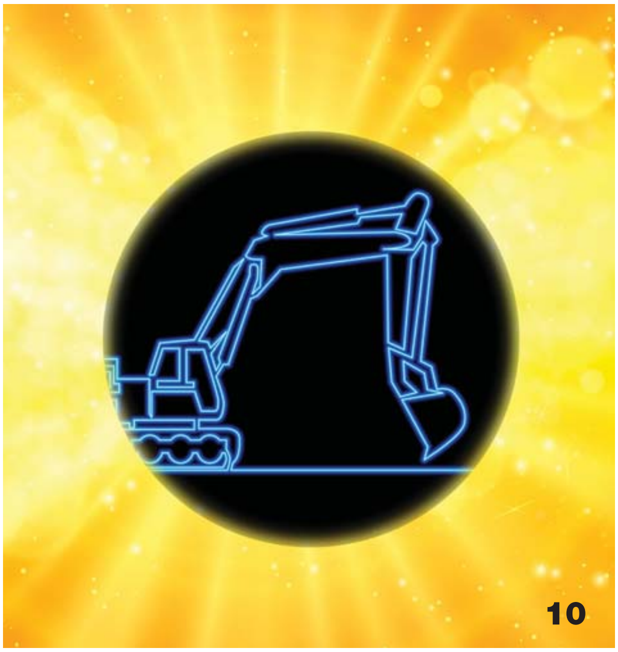

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POWER&MOTION

VOLUME 76, ISSUE 3

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Power & Motion Technology (USPS Permit 254-960), (ISSN 2831-4883 print, ISSN 2831-4891 online) is published 6 times per year (January/February, March/April, May/June, July/August, September/October, November/December) by Endeavor Business Media, LLC. 1233 Janesville Ave., Fort Atkinson, WI 53538. Periodical postage paid at Fort Atkinson, WI, and additional mailing offices. POSTMASTER: Send address changes to Power & Motion Technology, PO Box 3257, Northbrook, IL 60065-3257. SUBSCRIPTIONS: Publisher reserves the right to reject non-qualified subscriptions. Subscription prices: U.S. ($86.25 per year); Canada/Mexico ($98.75 per year); All other countries ($123.75 per year). All subscriptions are payable in U.S. funds. Send subscription inquiries to Power & Motion Technology, PO Box 3257, Northbrook, IL 60065-3257. Customer service can be reached toll-free at 877-382-9187 or at powermotiontech@omeda.com for magazine subscription assistance or questions.

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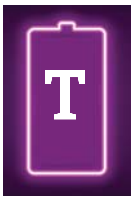
How is Fluid Power Coping with Electrification?



Today it's hard to go anywhere without hearing or talking about electrification, especially in regard to vehicles of various types. At the International Fluid Power Exposition (IFPE) and co-located CONEXPO/CON-AGG in March 2023 it was a key trend throughout the show for component suppliers and OEMs alike.

But what impacts will electrification have on hydraulics and pneumatics, and other motion control technologies? The industry consensus seems to be that the effects will be varied. This was the sentiment which came from *Power & Motion*'s recent survey of its audience on the subject as well, the results of which can be found starting on pg. 10 along with insights from industry members working in the electrification space.

There are of course many challenges associated with electrification, such as charging infrastructure and determining from where the energy for so many electric vehicles will come. Despite these roadblocks, the move to electric powered systems is growing, and anticipated to continue doing so in the foreseeable future.

During an interview with *Power & Motion* at IFPE 2023, Mourad Chergui, senior product manager at Delta-Q Technologies—a developer of on-board battery chargers—said the company estimates a larger share, close to 50%, of heavy-duty mobile equipment will be electrified by 2035.

Given the growth and impact of electrification on the fluid power industry, and the need for further education on it, we're using this issue to spotlight many of the technologies associated with this evolving trend.

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Emerson Acquires NI

Emerson sees value in merging NI's test and software products with its automation technology.

by Sara Jensen and Bob Vavra

Emerson announced on April 12 its entry into a definitive agreement to acquire NI (formerly known as National Instruments). It currently owns about 2.3 million shares of NI.

The acquisition of NI and its software-connected automated test and measurement systems will help to enhance Emerson's automation capabilities said Lal Karsanbhai, president and chief executive officer of Emerson, in the company's press release announcing the acquisition.

"Emerson will...gain a broader set of customers that relies on NI's solutions at critical points along the product development cycle. These capabilities provide Emerson industry diversification into attractive and growing discrete markets like semiconductor and electronics, transportation and electric vehicles, and aerospace and defense that are poised to benefit from secular growth trends. NI's business is well-aligned with our vision for automation and we look forward to working together to bring more comprehensive and innovative solutions to our customers, accelerate growth and position Emerson to deliver significant shareholder value, said Karsanbhai.

Emerson first announced its plans to acquire NI on Jan. 17. At that time, NI was valued at more than $7.6 billion. The public nature of the bid was unusual, but reflected Emerson's interest in NI, according to Karsanbhai.

"We have long admired NI and believe that combining its best-in-class electronic test and measurement product and software offerings with Emerson's industry-leading automation technology and software would enhance our ability to bring comprehensive solutions to a diverse set of end markets," he said.

The final agreed upon price for NI was $8.2 billion.

Merger Brings Market, Technological Benefits

Eric Starkloff, chief executive officer of NI, said the company has spent the last several months evaluating the future of its business and how to drive further value. After considering a range of options, the company feels the acquisition by Emerson provides the best outcome.

Emerson; NI; Dreamstime/ Mr.phonlawat Chaicheevinlikit

Emerson has acquired NI to expand its capabilities and markets.

"This transaction is a strong testament to the improvements and initiatives we've implemented in recent years that have transformed NI into a software focused company with higher growth, better profitability and lower cyclicality. We're thrilled that Emerson recognizes the value we've created and we believe they will help us build on our momentum to further position NI as a leading provider of software-connected automated test and measurement systems."

In its press release announcing the acquisition, Emerson outlines the five key rationale's for the merger:

- Balanced and Diversified End Markets—the company foresees test and measurement as a fast-growing market, and is an area it has previously outlined as one it would like to expand into. It will also bring more end markets into the company's portfolio, including semiconductor and electronics, transportation, and aerospace and defense. It is expected NI will help increase Emerson's end market exposure in discrete markets to 18% of sales, making it the company's second largest industry segment.
- Complementary Software and Innovation Capabilities—Emerson sees NI's technology stack as complementary to its own as well as a way to further accelerate development of higher value, cohesive industrial technologies. NI's open and interoperable software platform will enable customers to more easily adapt their systems as technology continues to evolve. Both companies have a shared focus on innovation which will aid with the continued development of new solutions for a range of customers.
- Sustainable Synergies—five years into the merger, Emerson sees $165 million in cost synergy opportunities through the application of its best practices. Among these will be productivity improvements and a streamlining of duplicate costs across business functions such as general and administrative, sales and marketing, and research and development. The companies will also be able to leverage Emerson's scale in manufacturing and supply chains.
- Strong Financial Profile and Returns for Shareholders—Emerson expects the acquisition to immediately benefit short- and long-term financial goals. The company anticipates NI's strong market position will bring sustainable underlying growth that will aid with Emerson's growth target of 4-7%.
- Unites Aligned Company Cultures—bringing together the two companies' focus on innovation and problem solving is expected to help further drive future development efforts. Emerson also sees the merger providing expanded career development and advancement opportunities for employees.

The board of directors for both companies have approved the transaction which is expected to close in the first half of Emerson's fiscal 2024. P&M

2023 IDEA Awards: Help us to Spotlight Product Design Excellence

For the third year running, we honor the top innovations in industrial design, engineering and automation — as nominated and voted upon by you, our readers.

by Staff

Endeavor Business Media

The 2023 Industrial Design, Engineering & Automation (IDEA) Awards highlight the key innovations in product design across the industry. IDEA Award winners and honorees are chosen by the engineering community for the *Machine Design*, *Electronic Design*, *Power & Motion*, *Microwaves & RF* and *Vision Systems Design* brands.

The 13 categories for the 2023 IDEA Awards have been updated to include emergent technology areas and broaden the range of engineering products and solutions. They include:

- **Additive Manufacturing**: 3D printing machines, materials and software, as well as interfaces to CAD and machine tools for post-processing.
- **Automation & Controls**: PLC, SCADA, and networks and software used to manage control systems and data.
- **Cabling and Enclosures**: Hardware meant to hold controls and electronics and monitoring the temperature, pressure, humidity, etc. inside the enclosure.
- **Communication**: Wireless and wired systems, modules and software that facilitate communication between chips, modules and systems.
- **Computing**: Edge computing devices and interfaces, as well as the compute, storage and communication modules and systems used to analyze data and assist design engineers.
- **Electric Motors, Drives and Components**: Electric motors and drives of all sizes and electrical and electronic components.
- **Sensors and Software**: Embedded sensors to measure speed, temperature, vibration, positioning and other operational parameters, as well as the software needed to effectively analyze the sensor data.
- **Electronic Components**: Passive electronic components like capacitors, transistors or diodes, connectors, cables, antennas and switches.
- **Design and Operations Software**: CAD, CAM, Digital Twin, modeling and simulation software as well as application tools and operating systems to assist the design engineer.
- **Fastening and Joining**: All mechanical and machine tool operations, welding, soldering and adhesives focused on metal or component joining as well as materials used to fasten and secure components.
- **Machine Vision**: Hardware and software designed to improve product quality, supply chain management and production throughput.
- **Motion Control**: Pneumatic, hydraulic, and electric systems and guides, including cylinders, ball screws, belts, chains and other actuators, as well as fluids, filters and compressed air systems.
- **Robotics**: Single-axis and multi-axis robots for assembly and supply chain use, plus cobots, AGVs and other robotic transport vehicles.

The finalists will be published and voting opened on June 9. For more information, go to the official IDEA Awards page at designengineering.endeavorb2b.com/idea-awards-call-for-entries. P&M

Understanding the Impacts of **Electrification on Hydraulics and Pneumatics**

Electrification presents challenges as well as opportunities to re-evaluate and improve upon the design of hydraulics and pneumatics.

by Sara Jensen

Composite: 39877997 © Lantica; 271536936 © Oksana Sazhnieva | Dreamstime.com
ALL CHARTS: ENDEAVOR BUSINESS MEDIA

The implementation of electrification, especially in mobile applications, continues to gain momentum as technology advances and more emphasis is placed on reducing carbon emissions around the world. With the growth in electric-powered systems has come the need to reassess other systems on a machine or vehicle, including hydraulics and pneumatics.

A recent survey of *Power & Motion*'s audience found about 50% of respondents have seen an uptick in requests from customers for electrification solutions. The other half was evenly split between those who are not experiencing an increase and those who are uncertain—indicating the varied levels of implementation in the breadth of industries served by fluid power.

While electrification is growing, the majority of respondents said it was influencing 25% or less of their fluid power component and system designs. However, 13.81% said electrification is influencing more than 50% of their designs which demonstrates the impact it is having on some hydraulics and pneumatics companies.

Almost 70% of respondents anticipate further growth in electrification related solutions in the coming years, making it vital for the fluid power industry to continue monitoring trends in this space and evaluating its place within it.

How Hydraulics and Pneumatics Could be Affected

As electrification has grown in many of the fluid power industry's key markets—such as construction equipment and automotive—many companies have already developed or are working on solutions specifically for electrified applications.

In addition, much of the industry is assessing the ways in which hydraulic and pneumatic systems could be redesigned. Doing so is necessary not only to meet the unique requirements of an electrified application but also to enable performance enhancements.

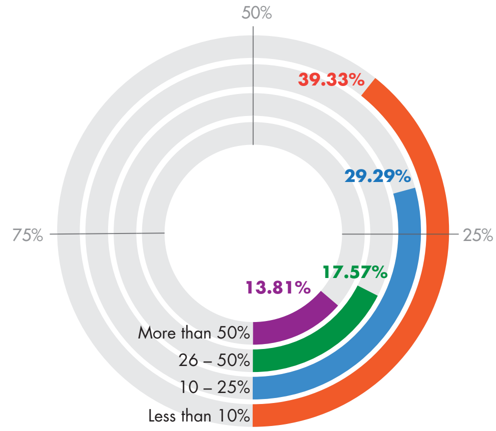
Improving the efficiency of fluid power systems is a key development area. Survey respondents noted efficiency improvements as one of the top impacts to hydraulic and pneumatic systems due to electrification—with 51.04% indicating as such. Ensuring all systems perform efficiently reduces energy draw from the battery, helping to extend time between charges which benefits vehicle range and productivity.

These efficiency gains are achieved by better applying power as it is required. "The exact power you need is given to an actuator, no more, no less," said Carl Seguin, in charge of engineering at Smart Reservoir Inc., in an interview with *Power & Motion*.

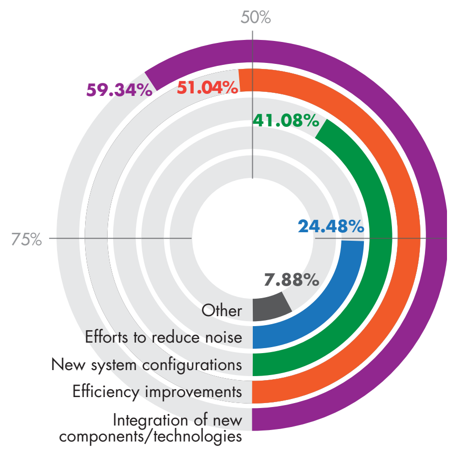
Traditionally, a hydraulic pump runs at a constant speed even though it does not need to, explained Seguin. This causes excess energy to be created and wasted, equating to inefficiencies. Use of variable frequency drives (VFDs) has grown in recent years to allow changes in pump speeds for more accurate, efficient flow. "That's a positive side of electrification, [using] the right amount of energy to do work," he said.

The largest impact noted by survey respondents, at 59.34%, is the integration of new components and technologies. This can include integration of more electronics, such as sensors, to improve precision which can aid with efficiency improvements.

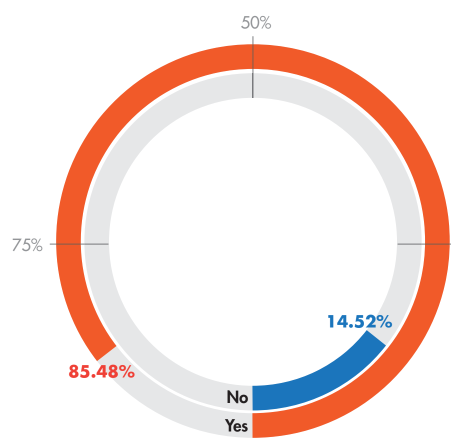
Additional impacts respondents pointed to include the creation of hybrid hydraulic systems and energy recovery capabilities. The latter is not new, but a growing method within hydraulic systems to aid efficiency improvements. Sun Hydraulics' ENERGEN valve is a recently introduced example. The valve converts hydraulic flow into electric energy by



What percentage of your fluid power component and system designs are now influenced by the move toward electrification?



What impacts are you seeing to hydraulic and pneumatic system designs due to electrification?



Do you see opportunities for the fluid power industry with the electrifica of machines and vehicles?

capturing and converting otherwise wasted energy. It essentially acts as regenerative braking for fluid power said one company executive during an interview with *Power & Motion* at the International Fluid Power Exposition (IFPE) 2023.

Drive System Design—an engineering consultancy focused on future powertrains and associated technologies—sees customers who have traditionally used hydraulics for propulsion or auxiliary components considering replacing some or all of them with electrified counterparts said Jason Schneider, principal engineer - team lead, Electrified Powertrain, in an interview with *Power & Motion*. "There's efficiency improvements to be had and controllability improvements," he said. "And there's even things on the NVH (noise, vibration and harshness) side [because] electronics are typically quieter than hydraulics and pneumatics, and maintainability as well."

Initial components typically considered are mechanically driven pumps or hydraulic motors which could be replaced with electric motors. If replacing those, hoses and other components feeding into the pump or motor can also be replaced which can provide space and weight savings—helping to ensure efficient battery use.

Electrification Brings Opportunities

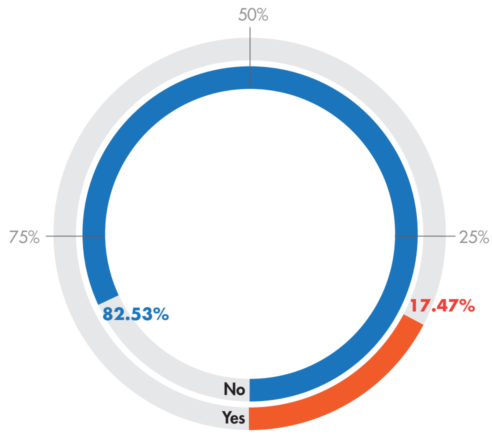
An overwhelming majority of survey respondents, just over 85%, see opportunities for the fluid power industry due to electrification. Much of this comes from the technological changes noted previously. Many respondents indicated the ability to improve precision and control, benefitting efficiency as well as the productivity of a machine—more precise movement of an excavator arm, for example, helps to reduce rework which keeps projects moving in a timely manner.

One respondent noted the better control provided by some systems could help to justify the additional costs and complexity associated with electrification.

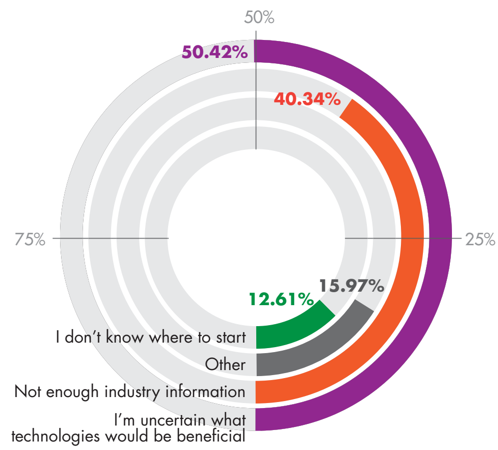
It is possible to rethink the size, layout and other design aspects of fluid power systems as well. One survey respondent noted the ability to reduce the physical size of hydraulic power units (HPU) as an opportunity. Doing so can help to minimize space claim which is an important consideration, especially in mobile applications as batteries account for much of the space and weight in a vehicle. Reducing the size of other components helps to compensate for this.

Additionally, power needs may be reduced compared to traditional applications therefore a smaller HPU is more desirable from a cost and energy consumption standpoint.

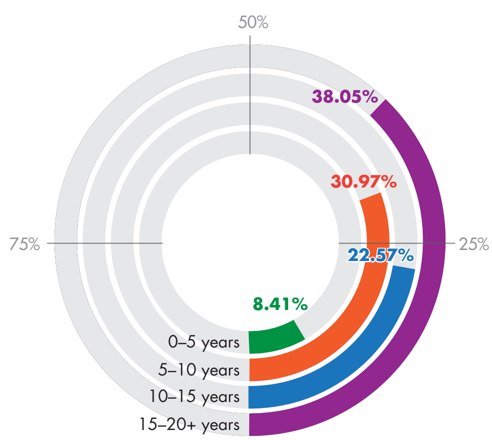
For its proof-of-concept wheel loader electrification project, Danfoss Power Solutions' Editron division found rethinking the entire system architecture of the machine was the best approach. This included a reassessment of the hydraulics system. By separating the propel and hydraulic work functions, the company found it could improve the efficiency of these systems and the overall machine.



Do you foresee hydraulics and pneumatics ever being completely replaced as industries electrify more machines and vehicles in the coming years?



What challenges do you face when it comes to implementing changes or new solutions for electrification?



When do you expect electrification to encompass a majority share of the markets fluid power serves?

Additional opportunities cited by respondents which electrification could bring to fluid power include the ability to improve accuracy and repeatability, reductions in oil leaks—and thus environmental impacts—increased use of electrohydraulics, and easier implementation of closed loop controls, to name a few.

However, it was also evident from the survey, and most discussions the *Power & Motion* team has with members of the industry, that hydraulics and pneumatics are not going anywhere. Over 82% of survey respondents said they do not foresee fluid power components ever being completely replaced as electrification continues to grow.

While there have been some examples of hydraulic systems being replaced with electric actuators and other electronic components—most notably Moog Construction's work with equipment manufacturers Komatsu and Bobcat—many note the power density provided by hydraulics will still be required in many applications, such as large construction equipment.

S.JENSEN

"Electrified systems won't be able to supply the same amount of power for the higher power applications where pneumatics or hydraulics are currently used," said Schneider. In some applications it will not be possible to achieve electrification or even make sense to do so, necessitating a thorough evaluation of the application and its requirements.

Technology and Industry Challenges Remain

One of the top challenges associated with implementing changes or new solutions for electrification for survey respondents, at 50.42%, is uncertainty about what technologies would be beneficial. This was closely followed by 40.34% indicating the lack of industry information as a challenge.

Both were factors the National Fluid Power Association (NFPA) set out to address when it established its electrification task force in 2022. The task force brought together members of the industry to discuss implications of electrification for the fluid power industry as well as help provide hydraulics and pneumatics manufacturers with more information on this trend.

NFPA's Electrification in Fluid Power Task Force released a report in early 2023 containing its final consensus which will be used to educate the industry and help the association refresh its Technology Roadmap—a project which is currently in process and guides the technology needs of the fluid power industry.

The report defines electrification and its many terms, predicted impacts to fluid power as well as ways the industry could effectively market the hydraulics and pneumatics technologies which will still be required for years to come.

Another key challenge noted by survey respondents was the complexity of systems due to electrification. Schneider said some of this comes from the increased controllability brought about by inclusion of electronic components. "If you want to do more clever things to get more efficient, you're going to drive the complexity of the controls," he said which can be a challenge for design teams.

The inclusion of more sophisticated electronic components will also bring a need to appropriately train technicians when repairs are necessary, said Seguin. Though electronics may require less maintenance than hydraulics and pneumatics, specialized training is necessary to not only understand potential issues when they arise but also ensure safety while working with these systems.

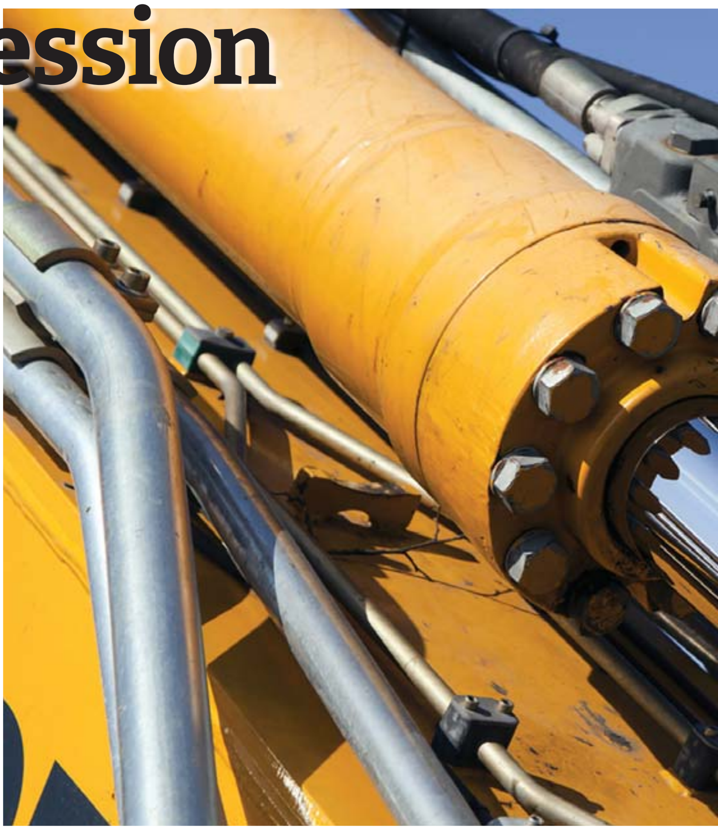
Survey respondents also noted challenges associated with customer hesitation, the lack of available technology and the need for a skilled workforce capable of developing necessary technologies.

According to Sequin, there are many pros and cons to consider with electrification such as the efficiency gains possible through improved control of hydraulic components. However, there is also the need to consider the larger factors associated with electrifying vehicles and machines such as the charging infrastructure necessary, where the energy to power so many electric vehicles will come from as well as the higher initial costs of going electric.

While there has been rapid growth of electrification in recent years, it remains unclear just how much it will become a part of the industries served by fluid power. A number of survey respondents believe it will take another 15-20 years before electrification encompasses a majority share of the markets utilizing hydraulics and pneumatics. However, this was closely followed by those who see it becoming more prevalent in the next 5-10 years.

There are several factors driving the push toward electrification and despite the confusion and complexity it is causing for many in the fluid power industry, it is also presenting several opportunities which could benefit hydraulics and pneumatics in the long term. P&M

A "Good" Recession for Hydraulics and Pneumatics



Although the economy is in a mild recession, the fluid power industry and most of its customer markets are forecast to be minimally impacted.

by Sara Jensen

During the National Fluid Power Association's (NFPA) Spring Economic Webinar, Jim Meil of ACT Research provided an overview of current market conditions and the potential impacts for the hydraulics and pneumatics industry.

Meil's key takeaway throughout the webinar was that yes there is a recession, but it should be described as mild. Several markets are flat or down slightly, and the economy will be a bit of a mixed bag. Sectors such as technology and housing are seeing a sharper downturn after the positive market conditions experienced in 2020 and 2021 while others, such as automotive, have a more positive outlook due to pent-up consumer demand. He also emphasized this recession will be nothing like what was experienced in 2008-2009.

DREAMSTIME/SERJLOGRUS

Pneumatics are in a flat to down trend, but should see a boost in 2024 likely aided by rebounds in the automotive market, a key sector for this portion of the fluid power industry.

Factors Impacting the Economy

Meil began the webinar by outlining the factors from 2022 which set the stage for 2023's economic outlook—two of the most impactful being Russia's invasion of Ukraine and the U.S. Federal Reserve starting its series of interest rate hikes. The latter he said really set the economic tone for the year while the Russia and Ukraine conflict led to higher oil prices, impacting a variety of sectors and consumers, and contributed to inflation.

In conjunction, there remains the supply chain constraints and impacts of COVID-19 which began in 2020. Labor challenges, inflation, the current recession and the potential for a banking crisis—it is too early to tell if this will occur—are also in the mix, making 2023 the fourth consecutive year of shock as Meil described it.

Overall, the global and U.S. economy is in a good news/bad news situation. Factors such as the labor market and high industrial commodity prices are negatively influencing it while energy prices are down from their peak and both consumers and businesses continue to spend on big ticket items despite expressing concerns about the economy.

As such, he said crisis management and flexible responses will be critical over the course of this decade. He also said it is important to remember we are in an inflationary era and that must be kept in mind when looking at any economic data or forecasts.

Hydraulics and pneumatics are forecast to weather the current recession better than other sectors.

DREAMSTIME/VIEW7

Continued strong demand in the mobile equipment markets will benefit hydraulics manufacturers who are continually bringing new products to market to benefit OEMs, such as these components displayed by Danfoss at IFPE 2023. S. JENSEN

Expectations for Hydraulics and Pneumatics

According to Meil, shipments for fluid power components trended up through the end of 2022 at about a double-digit pace (around 10.7%). But at the same time, orders were coming down when adjusting for inflation—which is necessary to do in the current inflationary environment.

Deflated figures for fluid power orders show they were flat to down over the last 15-18 months. This indicates some of the pent-up demand over the past couple of years is starting to slow said Meil.

Pneumatic orders and shipments in 2022 also experienced a relatively flat year when looking at deflated data. Over the past 12 months he said the orders and shipments trend has been up about 2%, but down compared to the past 2-3 years and not as strong as it was in the middle of 2021.

For total hydraulics, Meil said there is a lot of volatility in this segment but the key takeaway is orders, once deflated, have been slipping and a turnaround is coming for overall shipments. This is likely due in part to backlogs now being worked off by hydraulics manufacturers and the cushion provided by pent-up demand disappearing.

Mobile hydraulics are experiencing a similar story with orders, on a volume basis, peaking in late 2021, early 2022 while shipments rose. Again, this indicates backlogs are declining and pent-up demand is waning which could lead to a turnaround for this segment in the near future.

However, the story for industrial hydraulics is slightly different. Orders for this segment have been flatlining for the past two years. Shipments are going up, so there could be more opportunity for manufacturers of hydraulics for industrial applications.

Other hydraulics has been on a more positive trend with both orders and shipments trending up, and the short-term outlook is promising. Meanwhile, other fluid power is flatlining, but as Meil pointed out, given the current economic environment this is not necessarily a bad thing.

Although many of the fluid power segments have been flat to down over the past year, forecasts for 2023 are relatively positive, especially given the current economic situation. On a volume basis, and stripping out inflation, Meil provided the following shipment forecasts for 2023:

- Total fluid power – up 3%
- Hydraulics – up 5%
- Mobile hydraulics – up 5%
- Industrial hydraulics – up 4%
- Other hydraulics – up 6%
- Pneumatics – down 2%
- Other fluid power – 0%

Fluid power shipments in 2024, again on a volume basis with inflation stripped out, is forecast to be similarly positive though slightly down from 2023:

- Total fluid power – up 5%
- Hydraulics – up 3%
- Mobile hydraulics – up 1%
- Industrial hydraulics – up 4%
- Other hydraulics – up 3%
- Pneumatics – up 4%
- Other fluid power – 0%

Positivity in Customer Markets

In general, the customer markets served by hydraulics and pneumatics are forecast to be relatively positive in 2023 which will benefit the fluid power industry.

DREAMSTIME/KAMSKI59

Agricultural equipment, a key market for mobile hydraulics, will remain in positive territory due in large part to high crop prices which are aiding farm incomes.

Mobile Equipment

Construction equipment—one of the largest customer markets for fluid power, particularly hydraulics—is on a positive trend. Despite higher interest rates, demand is strong likely due in part to the prospect of investments coming down the pipeline from the infrastructure bill.

On a volume basis, with inflation accounted for, U.S. construction equipment shipments are currently forecast to grow 3% in 2023 and 7% in 2024 which should benefit the mobile hydraulics market.

The mining, oilfield and gas equipment market is not experiencing the glory days of 10-14 years ago, said Meil, but is currently aided by somewhat higher oil and gas prices. However, the volatility of these prices is also a hinderance because it is handicapping investment in the oil patch, he said.

U.S. mining & oilfield equipment shipments are forecast to rise 3% in 2023 and 6% in 2024, again on a volume basis with inflation stripped out.

Agricultural machinery, another large customer segment for hydraulics, will benefit from the currently high row crop prices—which are due in part to the Russia and Ukraine conflict. Higher crop prices equate to more money for farmers, enabling them to spend on new farm equipment. Meil noted there is some vulnerability for this market depending on the outcome of the Russia and Ukraine conflict, the direction of the U.S. dollar and potentially higher interest rates but in general, the agricultural equipment industry is fairing well.

Good News	Bad News
Consumers are spending as long as jobs are available	Banking problems could linger and expand
Global economy has been surprisingly resilient	Federal Reserve continues to increase interest rates but without a solid plan
Pent up demand from 2022 is benefitting 2023	Labor market is difficult
Energy prices are down from their peak in mid-2022	Credit crunch is taking place
Inventories are generally lean	Industrial commodity prices remain high
Small business confidence is generally high	Consumer and business confidence shaken
Consumers and businesses talk about being worried, but continue to spend money on big ticket items	U.S. dollar is off its peak but is still strong

Jim Meil of ACT Research outlined the good news/bad news factors currently impacting the U.S. and global economies.

S. JENSEN

The Association of Equipment Manufacturers' (AEM) most recent data on tractor and combine sales in the U.S. and Canada, at time of publishing, shows tractor sales in the U.S. have declined, other than gains in the 100+ hp and four-wheel drive segments. Combine sales in both countries continue to climb.

Forecasts for U.S. farm machinery shipments, on a deflated volume basis, is growth of 7% in 2023 and 5% in 2024.

Manufacturing

Over the past 24 months, the trend for material handling equipment has been generally positive said Meil. It is likely to remain strong with the continued investments in warehousing, distribution and e-commerce as well as some strength in the manufacturing industry.

U.S. material handling shipments are forecast to rise 4% in 2023 and 5% in 2024, on a deflated volume basis.

Industrial machinery and metal working equipment are the two fluid power customer segments with a less positive outlook in the coming year. For the latter, the aerospace and automotive markets are those which are having an impact.

This is due in large part to changes in tooling being made to accommodate production of electric vehicles. There is a reinvestment away from metalworking machinery toward electrical which is where most of the capital budgets are being spent said Meil.

As such, U.S. industrial machinery shipments are forecast to be down 1% in 2023 but up 3% in 2024. U.S. metalworking equipment shipments will decline 4% in 2023 and be flat in 2024. Both segments' figures are volume based and deflated.

Light- and Heavy-Duty Vehicles

The automotive and truck segments are among the most positive for the fluid power sector in the coming years.

Between 2013 and 2020, roughly 17 million cars were sold in the U.S. Unfortunately, the COVID-19 pandemic hit the market hard as fewer people were leaving the house and thus did not need a car. As a sense of normalcy returned, vehicle sales began to increase but production issues—due to supply chain constraints—made it difficult to purchase a car.

The automotive industry has started to work its way out of these issues and in 2022 achieved sales of 13.8 million said Meil. Pent-up demand from the past few years is expected to help further drive sales, with a 7-8% increase currently forecasted.

Class 8 trucks are prospering unusually well right now said Meil. Although data may indicate orders are slipping, he said orders in the backlog are quite strong. They are so strong that commercial vehicle OEMs are limiting orders as the backlog is already stretched out to the end of 2023 and into 2024. As such, orders appear to be going down, but customer demand remains; it is just a factor of OEMs controlling order intake so they can ensure delivery to customers.

North American Class 8 truck production is forecast to be in the range of 304,000 units in 2023 and 278,000 units in 2024. As Meil explained, because these figures are actual unit volume numbers, they do not need to be adjusted for inflation like those in the other customer markets. He also noted the standard production volume in a good year is typically about 260,000 units, so anything close to that is positive.

Like the Class 8 truck market, the medium-duty truck industry is experiencing strong backlogs and continued high demand which will benefit the industry, and thus fluid power suppliers, in 2023 and 2024.
S. JENSEN

Medium-duty trucks (Classes 5-7) are facing a similar scenario. Backlogs are at record levels and production continues to be strained said Meil. However, those constraints are gradually being lifted. This segment is forecast to see production volumes of 242,000 in 2023 and 250,000 in 2024.

Key Takeaways for Future Business Planning

While Meil said it makes sense to consider the economy in a recession, it is different from the average recession as it is mild compared to others in history. He anticipates it will have a very light touch on the fluid power and machinery markets, unlike ordinary recessions which typically impact all sectors and people. Instead, this recession will impact some businesses, like technology and housing, but not others.

As *Power & Motion* has previously reported, the economy is slowing after the strong demand experienced over the past two years. But there will still be growth, just not at the levels previously experienced.

Meil said the weakest parts of 2023 should be reached by summer and fall with economic improvements anticipated late in the year. Although the recession is currently forecast to be mild, there are risks to monitor in 2023 which could further impact the economy and various market sectors, such as fluid power:

- global security
- accelerating inflation and even higher interest rates
- another black swan event
- the three C's of China, COVID and cyber warfare.

Regarding inflation and interest rates, there are signs progress is being made and further hikes will not occur. Inflation is at 6%, down from its original high of 9%, indicating the Federal Reserve's interest rate increases have helped. The goal is to reach an inflation rate of around 2%. Barring any unforeseen shocks to the economic system, Meil said there is optimism victory on overcoming inflation could be declared in late 2023, early 2024 which could lead to an easing of interest rate increases.

As far as another black swan event, he said this could come in the form of a banking crisis or if the debt ceiling debate in Washington D.C. goes unresolved, either of which could cause major issues for the broader economy. None of this is for certain, but are factors to monitor over the coming months.

He said if a business can manage through the varied issues which arise throughout the decade and be prosperous, it should be in a good position and pat itself on the back—but then be ready for the economic challenges to continue. **P&M**

Improve Electric Motor Efficiency with Increased Phase Counts

An analysis of electric motor efficiency and how it can be improved by increasing phase counts.

by Kyle Hagen

A linear permanent magnet brushless DC motor.

A little over 200 years ago, we first learned how to create magnetic fields using electricity. Today, this concept is used broadly in electric motors across many industries. With such relatively little time spent innovating this invisible and non-intuitive phenomenon, it's no wonder that improvements to efficiency are still being found.

In this article we will focus on optimization of the commonly used Permanent Magnet Brushless DC motor (PMDC). These motors have become widely popular due to their efficiency and high force densities.

Efficiency improvements to PMDC motors are welcome as energy costs rise and applications like electric cars and factory automation strive to do more with less. The optimization discussed finds improvements to efficiency and of electric motors by changing the way they are both constructed and driven.

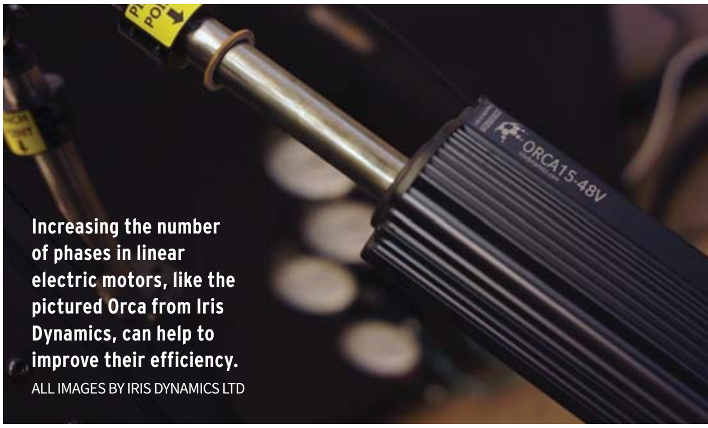
For simplicity the discussion here will relate to linear motors and, to avoid some nonlinearities and other complications, this discussion will focus on "air-core" motors, or those not using iron within the stator. With that said, the concepts here reach beyond the simplified examples—for instance to rotary motors, and motors with an iron-core.

Background on Electric Motor Designs

Basic Anatomy

The discovery of electromagnetism found that moving electrical charges through space results in magnetic fields swirling around them. Engineers took this phenomenon and built machines which focused generated fields onto each other to produce force and motion.

We call the copper windings of these machines a motor stator. The stator is powered and generates magnetic fields which interact with a second part in the motor called the slider (or rotor in a rotary motor).



Increasing the number of phases in linear electric motors, like the pictured Orca from Iris Dynamics, can help to improve their efficiency.

ALL IMAGES BY IRIS DYNAMICS LTD

Commutation

The nature of electric motors is such that the fields generated by the stator must continuously change with motor position. Commutation is the name for this. Modern brushless motors are commutated intelligently, so that the fields in the motor act together and not in conflict, and so the motor produces force and motion efficiently.

The way stators are arranged and commutated will be the heart of this article. First though, a little theory relating to how windings in the stator produce forces.

There are some positions of the motor where a particular winding will generate its "optimum" amount of force per current running through it. There are other "useless" positions where the same winding will produce no force, regardless of the amount of current running through it. Then there are all the positions in between, where the force-per-current of that winding will gradually sway from optimum to useless, to optimum in the other direction, and back again.

If the amount of force per current of a single winding within a motor is plotted versus the motor position, the resulting graph will typically look something like *Fig. 1*.

The shape of this plot will depend on various aspects of the motor's construction, but it always follows this general trend of smoothly flowing from optimal to useless and back to optimal, in alternating directions.

Motor Position and Electrical Angle

In the *Fig. 1* plot, the x-axis measures the "electrical angle" which measures how the rotor/slider of a motor aligns with the stator. The important concept here is that over the full travel of a motor (i.e., 360 deg. of rotation for a rotary motor, or the stroke length of a linear motor), there will often be more than 360 electrical degrees, and the plot above will repeat.

For example, a rotary motor having a 6-pole rotor (three magnet pairs) would see this plot repeated three times in series. This motor would have a total of 1,080 electrical degrees over its 360 mechanical degrees of motion.

Linear motors in general have total electrical degrees equal to 360 times the stroke length of the motor divided by "pole pitch," or twice the distance between adjacent magnets in the slider.

For this discussion, we can just concentrate on 360 electrical degrees of motion—noting that commutation will repeat multiple times per revolution or over the total stroke length. And we will ignore the nuances of when a linear motor's slider retracts into the stator.

Looking at All the Windings in a Stator

While the *Fig. 1* plot looks at the force-per-current of a single winding at various electrical angles, a similar plot can examine the force-per-current of all the windings in the motor at once, at a fixed electrical angle. As the motor moves (i.e., as the electrical angle changes) this plot will shift left and right.

Fig. 2 plots the force-per-current of the stator windings throughout a linear motor. Five different slider positions are shown to illustrate that as the slider moves, the force-per-current of each of the windings in the stator changes. This linear motor has a slider pole pitch of 50.8 mm and the stator has 6 poles, which implies the stator is 6 × 50.8 = 152 mm long.

How do we Make it Go?

The general idea behind commutating a motor is to provide power to the windings that can produce forces efficiently (i.e., those having high force-per-amp magnitude), and not provide power to any useless windings (i.e., those having zero force-per-amp). As the motor moves, the windings that should and should not get power change with it.

Ideal Control

What does perfect commutation of a motor look like? This is a problem in which the required force is achieved, while the power losses from heat are minimized.

An important concept to understand is that force in a winding is linearly proportional to current, while power losses are exponentially proportional to current. The consequence is that it is important to use every winding in the motor that can produce force, and not simply drive the most efficient ones. This is seen with the following example:

Optimal Driving of a Two Winding Motor.

Consider a motor with two windings. Both windings have a resistance of 1 ohm. At a particular electrical angle, one motor winding has a force-per-amp of 2 N/A, while the second winding has a force-per-amp of –1 N/A. How can 4 N output be reached?

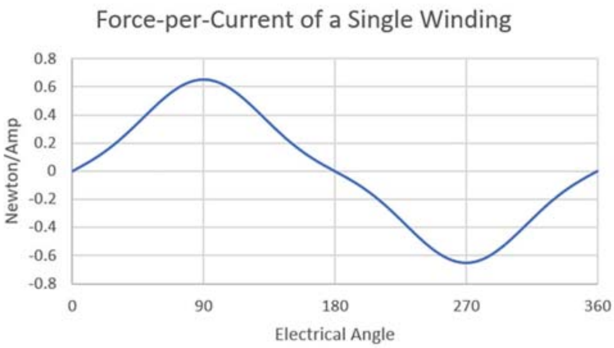


Fig. 1. Single winding force-per-current over 360 deg. of motor position.

One intuition might be to use the more efficient winding only: 2 amps into the first winding, 0 current into the second. This solution produces 4 N force at a cost of 4 Watts (W).

However, the optimal solution is to use 1.6 amps in the first winding, producing 3.2 N of force at a cost of 2.56 W, and −0.8 amps in the second winding, producing 0.8 N of force at a cost of 0.64 W. This solution produces the 4 N of force at a cost of 3.2 W.

While the above is just a simplified example, some math (not shown here) will find that the optimal way to drive a motor is to provide current to each winding proportional to the total required force and that winding's force-per-amp value, divided by the sum of the force-per-amp values squared of each winding in the motor…which is a mouthful.

Real Life Control

Why Ideal is Unrealistic

The conventional method of delivering power to a winding is to connect each of its leads to one or two MOSFETS (electrical

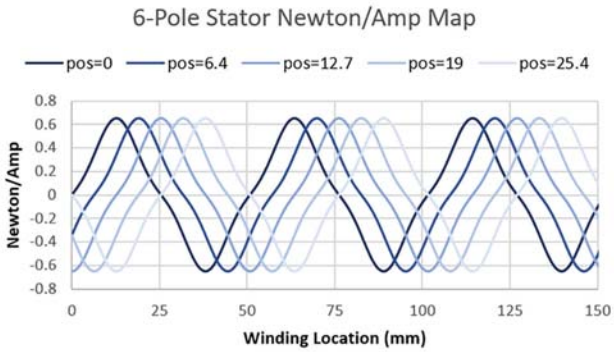


Fig. 2. Force-per-current of all stator windings in a 6-pole stator at various slider positions.

switches) which can connect and disconnect the winding leads to power. It is for this reason that windings in a motor cannot be powered individually. Rather, they are grouped into "phases" by series and sometimes parallel connections, and then wired to the motor driver as a group. This means that all the windings within a phase receive the same power.

So, we must therefore abandon perfection and consider the trade-offs of grouping windings together. Some windings within a phase may be "useless" while others in the phase are still able to contribute; or some windings within a phase may produce forces in opposite directions, canceling each other out.

The Use of Phases

Stators are grouped into at least two phases and the number of phases used determines the resolution of control that is had over the windings. Two phases means that half of the windings receive a certain amount of power, and the other half receive another amount. Three phases allow each third of the stator to receive a different amount, and so on.

To analyze the effect of using more or fewer phases, we can consider an example stator with evenly distributed windings of equal resistance and the same force-per-current profile, except that each profile is shifted according to the winding's position in the stator. We can divide this stator into 2, 3, 4 and 5 phases.

There is a property of magnetic fields called "superposition" which provides that the force-per-current of a phase is the sum of the force-per-current of each of the windings within the phase[1].

Fig. 2 shows the force-per-current of all the windings in a motor (at various electrical angles). *Fig. 3* illustrates dividing those windings up into 2 to 5 phases. Phase groupings are represented by the colored areas: green is phase 1, blue is phase 2, yellow is phase 3, purple is phase 4, and red is phase 5. The colored regions resemble the graphical representation of an integral, which reflect the property of superposition: a phase's response is the sum of the windings within it.

Like in *Fig. 2*, as the electrical angle changes, so will the shape of *Fig. 3*. The phase distributions (colored regions) will not move, but their area (and therefore their total force-per-current) will change.

A keen observer might find that the shaded regions would sum to zero, being that there are equal areas above and below the x-axis. And if the adjacent regions were wired without changing polarity, this would be true. Instead, every region is wired with alternating polarity.

However, when some windings within a single region (a consecutively colored block) are of alternating polarity, these windings will in fact 'fight' each other and sum to zero, indicating a waste of power. A clear example of this is seen

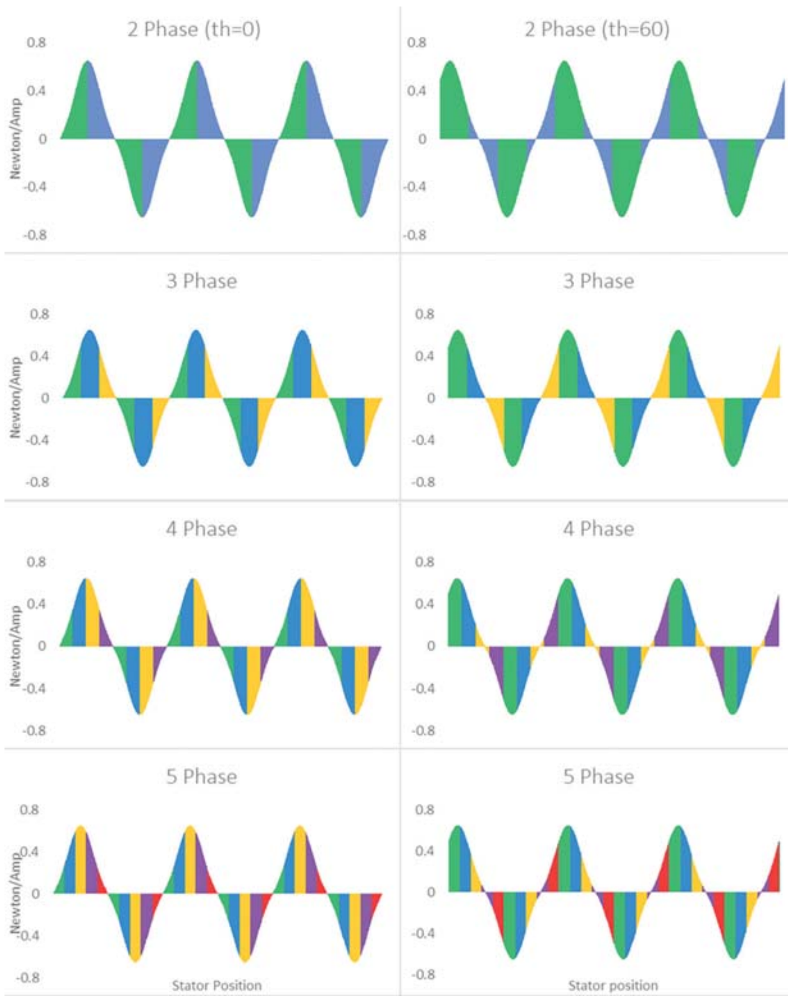


Fig. 3. Illustrations of grouping the stator from Fig. 2 into 2 to 5 phases.

in *Fig. 3*: phase 2 (blue) of the 2-phase arrangement suffers from significant losses due to cancellations when the electrical angle is 60 deg.

Ideal Control of Phases

In striving to control the phases in an optimum fashion, the same equation used to find optimal winding current can be applied to phases. Like the individual windings comprising a phase, a phase will have a force-per-current function which depends on the motor positions. We called the force-per-current function of the n^{th} winding $fw_n(\theta)$, and we can call the force-per-current function of the n^{th} phase $fp_n(\theta)$.

Equipped with this method of optimally powering a motor of N_p phases, we can investigate the advantages of building a motor with additional phases.

Improving Efficiency

If we start with the same number of windings, acting on the same permanent magnets, what's the difference between controlling it in 2, 3, 4 and 5 phases?

To find out, first the force-per-current of the various phases is found at each electrical angle. Next, for each electrical angle, we can find the required power to hit some arbitrary force. Then we can compare the power draw of each phase arrangement and know what is or isn't to be gained.

Phase Force-per-Current Functions

To find the force-per-current function of each phase, the force-per-current of all the windings comprising that phase are added (making sure to alternate polarity for consecutive poles).

Getting 100 N From Each Arrangement

If we need 100 N out of the motor, it will come with power losses. The amount of loss depends on the resistance of the windings, and how effectively current is applied to the windings. Using 5 phases provides a finer resolution of control over where power is delivered compared to 2 phases, and this should result in fewer windings fighting each other and more power getting to the more effective windings.

Number of Phases	Phase Resistance
2	18 Ohms
3	12 Ohms
4	9 Ohms
5	7.2 Ohms

Fig. 4. Example stator's phase resistances.

If the assumed total resistance of all the windings in the stator joined in series is 36 ohms, we can use the resistances for each of the phase arrangements shown in *Fig. 4*.

These numbers simply follow from the assumption that each phase consists of windings joined in series.

How Do Motor Constants Compare?

A motor constant is a measure of a motor's ability to transform power into force. This is often measured in force-per-square root watt.

In the example from this article, the discovered motor constants of each phase arrangement across electrical angles are found in *Fig. 5*.

So What?

If we start with the same number of windings, acting on the same permanent magnets, we find that controlling the stator in 2, 3, 4 or 5 phases results in a different power cost for the same force output.

This means for the same footprint and material, adding or removing phases from a motor design directly and significantly impacts the power efficiency of that motor.

Why Use 2-Phase Motors if They Burn 18% More Power?

With most industrial motors being wound in 2 or 3 phases, this might be a natural question at this point. Mostly, this comes down to tradition and complexity.

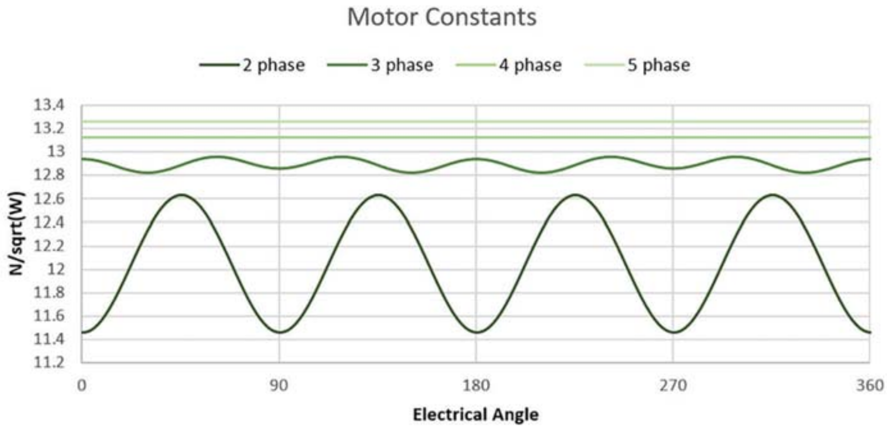


Fig. 5. Motor constants of 2-, 3-, 4-, and 5-phase arrangements.

Tradition

With less than 200 years of experience making motors, our society is far from arriving at an optimal solution. Engineers are always dealing with new tools arriving and the state-of-the-art evolving.

Initially, commutation was done with mechanical contacts (brushes), and the concept of driving the stator windings with any sort of optimal mathematics was totally out of the question. Fewer phases meant fewer mechanical contacts and fewer failures. Fair enough!

When brushless motors came about, they were essentially wired directly to the power distribution networks which were all 2 or 3 phases. Again, no precise control over phase currents could be had.

When methods of electrical angle detection (e.g., Hall-effect sensors and encoders) and motor driver technology advanced to the point that precise current control could be had, designers were encouraged to build 2- and 3-phase compatible systems that could serve the vast number of 2- and 3-phase motor bodies in existence.

Today, a great majority of motor drivers and control software available caters only to 2- and 3-phase motors.

Complexity

Intelligently controlling a motor to hit peak efficiency requires significant engineering: one needs fast and accurate current controls, fast and accurate electrical angle detection,

Efficiency improvements to motors are welcome as energy costs rise and applications strive to do more with less.

some knowledge of the force-per-current of the motor in question, and logic which ties everything together with low latency. So, even controlling 2 or 3 phases optimally is a tall order.

When the motor phases and the motor driver are remotely located, as they typically are, each phase requires power leads to be run between the motor and driver. These leads carry significant power, and significant fast voltage transitions that can cause radio wave interference (EMI) which could corrupt nearby sensor lines. Adding, for example, 4 more of these lines by moving to 4 phases from 2 phases is not only expensive but also potentially causes other problems.

Visit powermotiontech.com/21262644 to view more figures and equations.

The Potential Benefits of 4-Phase Motors

Despite the challenges, more reasons are coming up to get the most from electric motors. Rising energy prices might incentivize factories to optimize their motors to reduce power consumption. Extending range might incentivize an electric car manufacturer to invest in efficiency gains. Rapidly increasing prices for rare earth metals like Neodymium make squeezing more performance from less material more sensical.

Given the efficiency opportunities with 4-phase motors, more options are entering the market such as Iris Dynamics' Orca Series linear motors. The motors feature integrated drivers and advanced control algorithms which help to handle complexities and provide a good feature set with optimized power efficiency and force density at low voltages. P&M

[1]*In fact, this is only true when windings within the phase are connected in series. But while parallel connections in the stator will have implications for the motor driver and required supply voltage, there will be no effect on the motor efficiency, so we can proceed with this assumption for the sake of simplicity.*

This article was written and contributed by Kyle Hagen, CTO & co-founder, Iris Dynamics LTD.

The Road to Zero: Utilizing Electrification to Unlock New System Architectures

High-power electric machines are opening new classes of powertrain architectures, necessitating an understanding of each type and the applications for which they are best suited.

by Cameron Guernsey and Simon Nielsen

Use of a parallel hybrid system architecture helped the Logset 12H GTE forest harvester reduce its fuel consumption 20-30%.
ALL IMAGES: DANFOSS POWER SOLUTIONS

As the world aspires to reach net zero, electrification continues to be a focus for all types of applications, especially mobile machinery.

In many off-highway machines, the conventional system architecture is for the internal combustion engine to be the power source, with propulsion achieved through a closed-circuit hydrostatic drive system. Meanwhile, the work, steering and auxiliary functions are typically achieved through at least one open-circuit hydraulic system.

However, high-power electric machines are opening new classes of powertrain architectures in the off-highway industry by acting as the overall or auxiliary prime mover, powering hybrid drivetrains or being the traction motor in a fully electric vehicle application.

This is enabled by the key characteristics of the electric machines, such as their ability to distribute the prime-mover function more easily and optimally.

Other positive qualities include torque curve maximization starting at low speeds, the potential they offer for high conversion efficiency across a wide range of operational modes and their high controllability. The latter results from a combination of the physical characteristics of electric machines and the control algorithms in the inverter.

In this article the multiple system architectures possible for hybrid and electric vehicles will be explained, as well as how to choose the best option for an application.

Parallel Hybrid Systems

This architecture typically retains the original drivetrain design, but adds a motor-generator to the engine crankshaft and energy storage, which enables both the addition and subtraction of electrical power as required. This benefit unlocks peak shaving and the option to either downsize the engine or boost the overall power.

In parallel hybrid systems, periods of electric-only driving can be achieved if a clutch separates the engine and the electric machine. This can help machines start from a standstill or comply with emission-free zones and construction sites.

The overall benefits of a parallel hybrid system architecture are increased productivity, typical fuel savings of between 10-15%, and emissions and noise reduction. They are well suited for applications with high average utilization of power.

One real-world machine Danfoss has delivered with a parallel hybrid system architecture is the Logset 12H GTE forest harvester. During harvesting operations, the parallel hybrid design of this machine enables the engine to operate at a lower, relatively consistent engine speed of approximately 1,700 rpm. This charges a supercapacitor between tree processing before discharging the stored energy to supplement the engine during sawing and stripping operations. This operational profile produces higher productivity and reduces fuel consumption by 20-30%.

Series Hybrid Systems

Similar to the parallel hybrid system, the series hybrid architecture also offers the benefits of peak shaving and power addition, plus the possibility of electric-only operation—as long as the necessary auxiliary functions can be operated independently of the engine. The main difference is that the series hybrid drivetrain replaces the existing drivetrain and must be dimensioned to meet the application's full force and speed requirements.

The benefits of series hybrid systems are similar to parallel hybrid architectures, namely increased productivity and reduced emissions and noise levels. However, the fuel savings are even higher, generally coming in between 20-35%. Danfoss offers series hybrid architectures for applications seeking significant efficiency improvement despite the high average power level and overall energy storage requirements.

The Rockster R1100DE stone crusher is an example of an off-highway machine featuring a series hybrid system. The first-of-its-kind on the market, the machine's design features an electric powertrain for the crushing system and supercapacitors for cushioning against load peaks. Ultimately, this leads to substantial fuel savings of 16,000 L annually, a productivity improvement of 40%, reduced maintenance, and a relatively short payback period of only nine months.

Fully Electric Systems

A fully electric system typically powered by a high-voltage battery is the best option for mobile applications requiring exclusively zero-emission operation or maximizing energy efficiency. Danfoss offers several basic variations of fully electric system architectures.

The second generation MinCa 5.1. electric mine vehicle is one example of a fully electric product. This machine can operate for between 3-4 hours before its 50 kWh battery needs to be recharged. The MinCa 5.1. is an excellent example of how emission-free operation can enable significant cost savings through lower fuel and ventilation costs. Other benefits of the machine include reduced noise, vibrations and heat from the vehicle.


The Rockster R1100DE stone crusher uses a series hybrid system, enabling it to achieve 16,000 L in fuel savings annually.

For applications requiring the benefits of electric operation but where the ability to modify the machine or meet the capabilities of the existing powertrain is limited, a viable option is to simply swap the engine for an electric prime mover. While there may be more optimal approaches than this in some cases, it can be fast and effective and one of the quickest ways of introducing a battery-electric vehicle to a fleet. Additionally, an electric prime mover is up to 96% efficient, a significant increase compared to a diesel engine, which has an energy conversion efficiency of only around 30%.

This is the method Pon Equipment of Norway chose to achieve a battery-electric excavator in collaboration with Danfoss. Based on a CAT 323F hydraulic excavator, the machine's engine was replaced with an electric motor, with the vehicle also equipped with a 300 kWh battery. This enables between 5-7 hours of quiet, efficient and emission-free operation, plus supports the Norwegian government's push for zero-emission construction sites and climate neutrality by 2030.

Which System Architecture Best Suits a Machine

While there is certainly no single correct answer for the entire market, there are many factors to consider when deciding which system architecture best suits an application.

The need for zero-emission operation, the ability to modify base machine design, the capacity to recover energy and access to an energy source are all crucial aspects OEMs should consider. They should also think about whether they wish to maximize productivity or efficiency, prioritize the total cost of ownership or keep initial costs low and focus on high- or low-utilization duty cycles, as the answers to all of these questions will be crucial in identifying the right system architecture for their application.

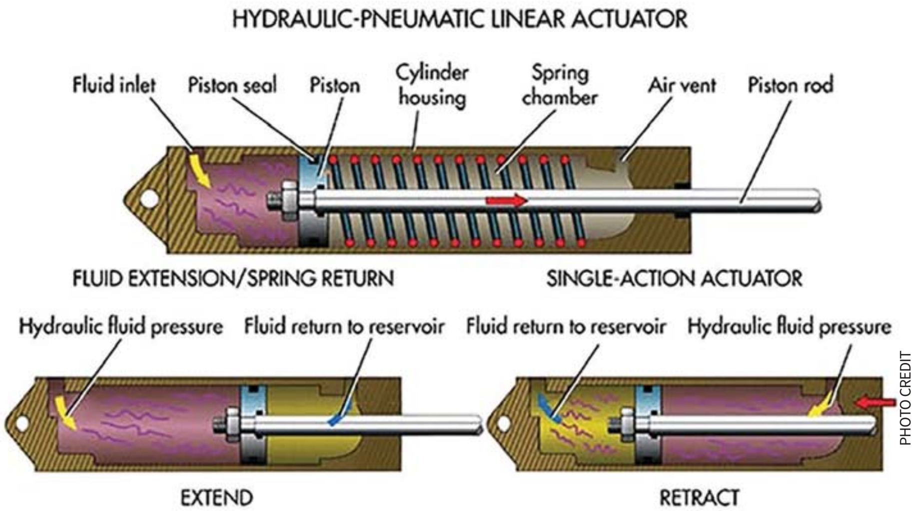
With an extensive portfolio of electric machines and power electronics, Danfoss Power Solutions' Editron division offers products covering various vehicle sizes, sub-system applications, and powertrain architectures. The company is leveraging years of application knowledge and expertise in hydraulics and mobile machinery to understand and develop these electrified off-highway solutions. By working directly with the OEMs, Danfoss offers support in helping its customers determine the best system architecture for a given application. P&M

This article was written and contributed by Cameron Guernsey, product manager at Danfoss' Editron division and Simon Nielsen, staff engineer at Danfoss Power Solutions.

Sorting Out Linear Actuators

A concise look at the characteristics and quirks of three common types of actuators: hydraulic, pneumatic and electric.

by Staff



A spring returns the actuator after its stroke (top). A spring returns the piston to it starting position and hydraulic fluid leaves the cylinder. A double-acting cylinder (bottom) has fluid entering both sides of the piston depending on the desired motion.

It seems almost all industries use linear actuators in some way—perhaps to move inventory, products or components, or to carry out manufacturing and assembly processes. They convert energy into a motion or force and are usually powered by one of three methods: hydraulics, pneumatics or electricity. Here's a quick look at each of these methods.

Pneumatics

Pneumatic actuators have a piston inside a hollow cylinder that is moved through that cylinder by pressurized air entering from a compressor or pump. This linear motion can move a load or create a force. The piston returns to its original position using a spring or pressurized air supplied to the other side of the piston.

Most aluminum pneumatic actuators carry a maximum pressure rating of 150 psi. They are available in bore sizes from 1/2 to 8 in. and can create 7,500 lb. of force. For higher forces, steel actuators have a maximum pressure rating of 250 psi with bore sizes from 1/2 to 14 in. They generate from 50 to 38,465 lb. of force.

ADVANTAGES

Accuracy. Pneumatic actuators routinely have positional errors of 0.1 in. and repeatability within .001 in.

Temperature resistance. Pneumatic actuators can withstand temperatures from −40°F to 250°F (–14°C to 120°C).

Safety. Pneumatic actuators do not use hazardous materials, so they pose no environmental or health hazards. They also do not use a motor so there is no possible magnetic interference, which lets them meet requirements for explosion protection and machine safety.

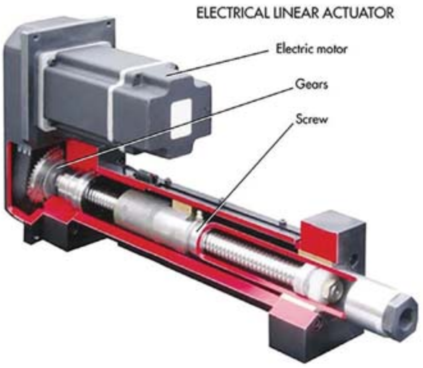
Low cost. The lightweight, durable actuators cost less than comparable hydraulic and electric versions. They also require little maintenance.

DISADVANTAGES

Compressed air. Pressure losses and air's compressibility make pneumatics less efficient than hydraulics and electricity. Compressor and air delivery can limit operations with lower pressures, resulting in lower forces and speeds.
The compressor must run and provide operating pressure even

if nothing is moving. And even though the air is easily available and free, it must be kept clean and at the proper humidity; if it gets contaminated by oil or lubrication, it will lead to downtime and maintenance. Compressed air is a consumable that must be paid for, and the air lines and compressor must be maintained.

Hard to upgrade. Pneumatic actuators must be sized for a specific job to be efficient; they cannot effectively be used for other applications. And if a factory wants to improve control and efficiency, technicians must install proportional regulators and valves—a costly and complex upgrade.



Hydraulics

Hydraulic linear actuators operate similarly to pneumatic actuators, but a pressurized incompressible liquid (hydraulic fluid) supplied by a pump rather than pressurized air moves the cylinder.

ADVANTAGES

High force. Hydraulic actuators are rugged and well-suited for generating forces up to 25 times greater than those possible with equally sized pneumatic cylinders. They also have horsepower-to-weight ratios 1 to 2 hp/lb greater than a comparably sized pneumatic motor.

Brakes. Hydraulic actuators can hold a force and torque constant without the pump sending more fluid or pressure, thanks to the fluid's incompressibility.

Flexible footprint. The pumps and motors needed by hydraulic actuators can be housed a considerable distance away from the actuators with minimal power loss.

DISADVANTAGES

Leaks. Hydraulics will leak, and fluid loss leads to less efficiency. Hydraulic fluid leaks lead to problems and potential damage to surrounding components and areas.

Complexity. Hydraulic actuators require lots of parts, including a fluid reservoir, motors, pumps, release valves and heat exchangers, along with noise-reduction equipment. This makes for large and difficult-to-accommodate linear motion subsystems.

Electric

Electric actuators convert electrical energy into torque that can then be turned into linear motion. For example, the motor could turn a thread lead or ball screw. A threaded lead or ball nut with threads matching the screw's is prevented from rotating with the screw. So when the screw rotates, the nut gets moved along the threads. The direction the nut moves depends on which direction the screw rotates.

ADVANTAGES

Accuracy. Electric actuators offer the most precise control; they have accuracies of ±0.000315 in. and repeatability below 0.0000394 in. They can be scaled for any purpose or force requirements.

Programmable. Electric actuators can be networked and reprogrammed quickly, letting operators preset or adjust velocity, position, torque and applied force. They also supply immediate feedback for diagnostics and maintenance.

Noise. They are quieter than pneumatic and hydraulic actuators.

Clean. There are no fluids in electric actuators (except perhaps for lubrication), so environmental hazards are minimal.

DISADVANTAGES

Cost. The initial cost of an electric actuator is higher than those for pneumatics and hydraulics.

Setup. Electric actuators are not suited for all environments. For example, unlike pneumatic actuators, they are not safe in hazardous and flammable areas. The motor can also be large, creating installation problems.

Overheating. Continuously running motors tend to overheat, increasing wear-and-tear on the reduction gear.

Difficult to upgrade. The motor chosen locks in the actuator's force, thrust, and speed limits. If a different set of values for force, thrust and speed is desired, the motor must be replaced. P&M

Advertiser Index

SICK DAX Linear Encoder

The SICK DAX linear encoder product family provides high-precision detection and reporting of the piston positions in hydraulic cylinders. These sensors are also capable of monitoring linear movements in machines.

Key features of the DAX linear encoders include:

- uses absolute measurement principle, eliminating need for reference run measuring range between 50 and 2,500 mm
- three design options to suit varied applications
- flexible system architecture allows customization for specific requirements
- diagnostic capabilities enable use for condition monitoring

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Festo VZXA Pneumatic Angle Seat Valves

Festo's VZXA line of pneumatically actuated angle seat valves feature a modular design which ease their installation and maintenance. The valves enable high volume flow control of water, steam and corrosive materials.

Key features of the VZXA angle seat valves include:

- wide temperature and pressure range capabilities
- stem, seat and seal stay inside valve body during maintenance, maintaining system pressurization
- reinstallation requires only valve body to be screwed into place
- modular design suits use in valve manifold applications

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Atos Explosion-Proof Electrohydraulics

Atos has developed a range of explosion-proof electrohydraulic components which benefit use in a range of applications. They are designed to provide high-performance control and simplified maintenance while offering the corrosion resistance and heavy equipment handling required of the application.

Features of the explosion-proof electrohydraulics include:

- provides high-performance motion control
- high corrosion resistance via zinc-based surface treatment, reaching up to 600 hours in salt-spray test
- on-board digital technology enables development of smart systems
- industry certifications such as SIL2/SIL3 according to IEC 61508, TÜV, DEKRA, UL and more

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Continental Shop in a Box

Continental's Shop in a Box is designed to provide an all-in-one solution to ease the creation of a hydraulic hose assembly. It contains a crimper and all the necessary accessories to produce Continental hose assemblies.

Shop in a Box includes:

- 96 × 36 in. work table
- crimper and die storage
- HS 150 hose saw
- fitting cabinet and bins
- 24 in. hose reel

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Electro-Hydraulic Systems Benefit Electrification of Heavy Machinery

by Sara Jensen

Electrification continues to grow in the heavy-duty mobile equipment industry. Although more common for compact construction equipment and agricultural machinery, among other applications, OEMs are working to expand the size and type of machines in which electrification can be applied.

As such, they are relying on component and system suppliers to aid with their development efforts. Because hydraulics in particular are, and will remain, a vital component of heavy machinery, several companies within the fluid power industry have expanded their development efforts into the electrification space.

Nott Company (Nott Co.), which specializes in engineered solutions for mobile and industrial fluid power, began working with customers on electrification solutions about 10 years ago. It helps OEMs develop both electro-hydraulic and full-electric systems which will meet their machine and application requirements.

Electro-hydraulic systems bring together electronic and hydraulic components and are seen as a way to help enable the transition to fully electric machines. Not all machine types are capable of using full-electric systems, particularly larger machines, or there are applications where it would not be a convenient option for end-use customers. For those instances in which full-electric systems are not an option or the OEM and its customers are not ready to go fully electric, electro-hydraulic systems provide an alternative in which many of the benefits of electrification can still be achieved.

Power & Motion recently spoke with DJ O'Konek, engineering manager at Nott Co., about current electrification trends and how the company is helping customers with the development of electro-hydraulic and full-electric systems.

***P&M:* How has Nott Co. seen full-electric and electro-hydraulic system development advance in recent years?**

DJ O'Konek: Since Nott Company entered the electrification world about 10 years ago, we've seen a lot of changes, especially in the last few years. There's been a lot of heightened interest [from] customers looking for modification of their equipment to electrified solutions, whether that's electro-hydraulic or full-electric systems.

On top of that, there's been a huge influx of mobile hardened products that can help facilitate doing this. When we got going way back when there was not the selection of components that is available today. So, it always made it very, very challenging to just come up with solutions for the customers. The nice thing is, though, the industrial world has been on this path for a really long time so it's just really a transitioning of those components into the mobile hardened world.


NOTT COMPANY

The other advantage too, is, as all of these [industries] transition over, components are becoming lower cost and the size of the packages are going down. The other thing we've seen a lot is [movement] towards higher voltages to handle bigger tasks with larger machines.

***P&M:* Is it mostly emissions regulations that are driving the push towards use of these technologies or are there other drivers Nott Co. is seeing in the market?**

DO: It's [emissions regulations] a factor. I also think that a lot of companies are trying to have a cleaner image. And I think there's just a lot of social awareness [which] is driving it as well. Customers are starting to expect to have those options too.

***P&M:* What are some of the key factors which should be taken into consideration when developing full-electric and electro-hydraulic systems?**

DO: Honestly, the biggest factor whether it's an electro-hydraulic or full-electric system is efficiency. Everybody is relying on batteries on the vehicles when you're doing this [electrification]. And it's not like you can run down to the gas station to get a can of electrons. So, efficiency becomes key to get the runtime that's required.

Next is really understanding the customer's requirements when it comes to runtime. When you're going through sizing the batteries and everything for the system, that is a huge detail. The other thing is duty cycle. A lot of these machines have existed in the market for a long period of time. Going through [and] analyzing the duty cycle [is important] so that you know where the power is being consumed.

Another thing that a lot of [OEMs] don't think about is [if there is] access to charging [and] what type of charging is available and are their customers going to want an onboard charger or are they going to have access to off-board chargers as well. So, all kinds of little details like that. P&M

**Editor's Note: The full Q&A can be read online at powermotiontech.com/21259431.*