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+ STATE OF THE INDUSTRY 2024: Optimism Ahead Despite Challenges

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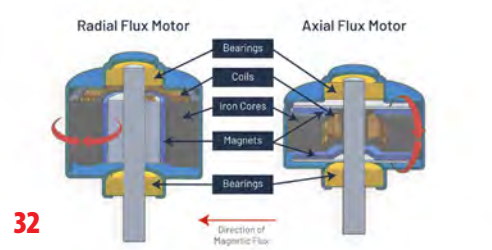

EDITOR'S NOTE

It's been quite a whirlwind the last few months and it's hard to believe how much things have changed. That said, there are some constants in the B2B world I have inhabited for the better part of 13 years now.

In the end, regardless of what side of engineering and manufacturing you're on, the goal remains the same: Improve productivity and meet consumer demand through innovation, automation and best practices.

Changing of the guard (from left): Kathy Wells, former Editor of OEM Off-Highway and now Editor-in-Chief of Equipment Today; Jodi Sage, Events and Marketing Specialist for IRONMARKETS; Chris Vavra, Editor of OEM Off-Highway.

That message was instilled in me from the many end users and OEMs I worked with as an editor for *Control Engineering* and *Plant Engineering*.

I was delighted to learn at MINExpo in Las Vegas and Battery Show in Detroit the priorities remain the same for the readers that form the bedrock of *OEM Off-Highway*.

That's what I will try to bring to you through thought leadership whether it be articles, webinars, video interviews, podcasts and more. I look to the reader to provide me with the insights to better enlighten the industries you serve. Check out my recaps from MINExpo and Battery Show on the work already being done.

Special thanks to my predecessor, Kathy Wells, for guiding me along in this transition process and giving me a head start. I also appreciated the advice I received from past editors of *OEM Off-Highway*.

This publication has endured for 40 years because of the message it provides to a special subset of the engineering and manufacturing world.

Looking forward to the next chapter in my journey and am happy to have you along with it.

Reach me at cvavra@iron.markets

MINExpo 2024 Recap:
Building Toward an Automated, Sustainable Future

Battery Show 2024 Recap:
Digital Automation, Innovation at Forefront

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OEM Off-Highway (USPS 752-770, ISSN 1048-3039 (print); ISSN 2158-7094 (online) is published 6 times a year: January/February, March/April, May/June, July/August, September/October and November/December by IRONMARKETS, 201 N. Main Street, 3rd Fl., Fort Atkinson, WI 53538. Periodicals Postage paid at Fort Atkinson, WI and additional entry offices. POSTMASTER: Send address changes to: *OEM Off-Highway, 201 N. Main St. Ste. 350, Fort Atkinson, WI 53538.* Printed in the U.S.A.

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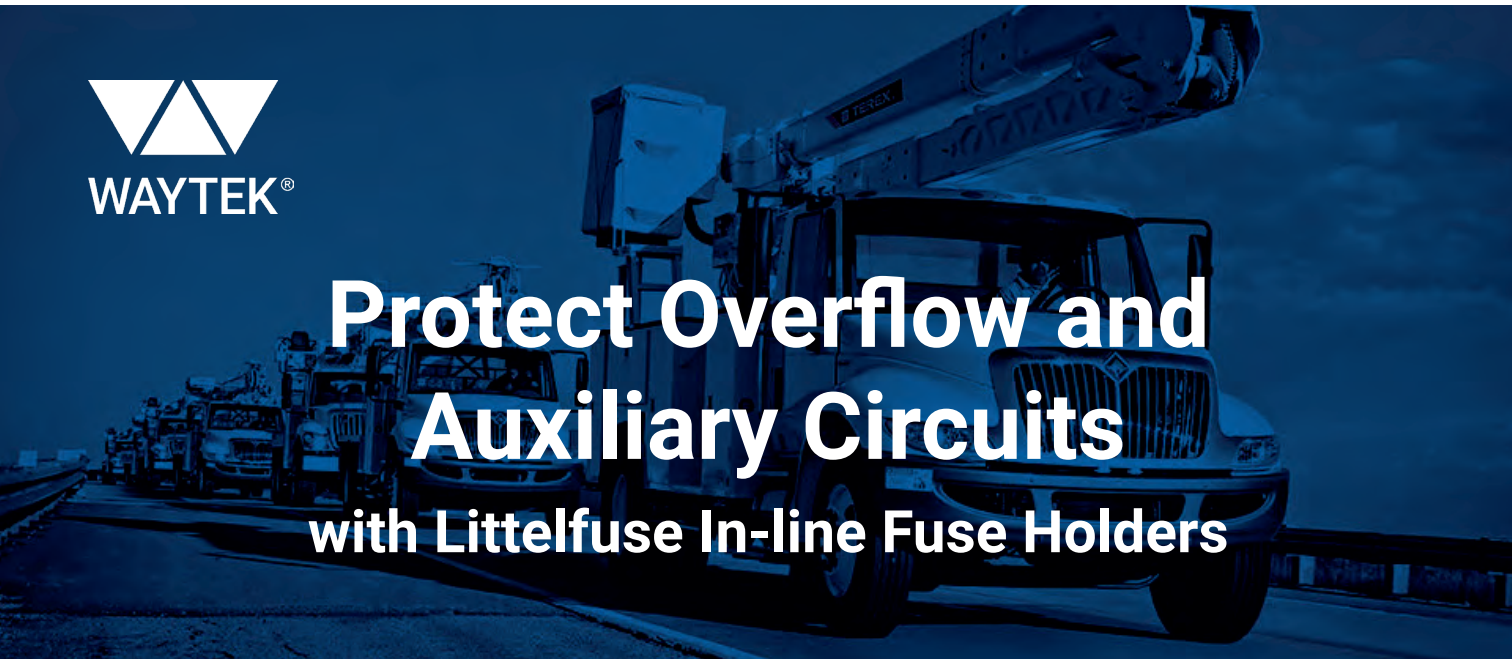

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Eberspächer

INDUSTRIAL PRODUCTION SLIGHTLY HIGHER, CONCERNS REMAIN

U.S. industrial production slightly ahead in September compared to 2023. However, the OECD Leading Indicator is mildly declining.

by Chris Vavra

Industry-leading economic firm ITR Economics provides heavy-duty equipment market trends to help OEMs stay up to date on top industry information and insights, which can help them make better decisions in 2024. The latest data reveals a mixed bag overall with U.S. industrial production slightly ahead in September compared to the same period in 2023.

However, conditions in Europe are down and the monthly rate-of-change for the OECD Leading Indicator is mildly declining, which is suggesting longer-than-typical lead times.

The following provides a summary of key observations across 13 indicators and areas of industry that contribute to today's global economic conditions.

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Editor's Note: Please note that this chart has been modified on the Y-axis to show the trend more easily. All data for charts are supplied by ITR Economics.

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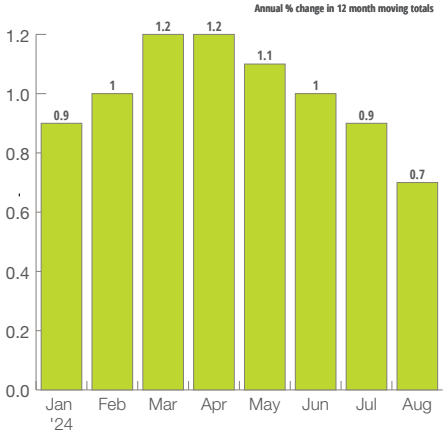
U.S. Leading Indicator

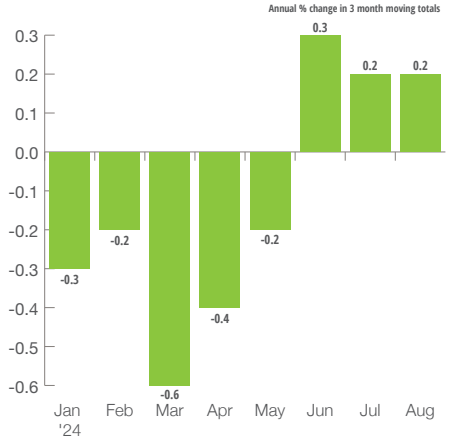
- The monthly rate-of-change for the U.S. OECD Leading Indicator is mildly declining. More data is needed to confirm if this directional change will hold.
- We are seeing a delayed reaction in the macroeconomic data relative to many leading indicators, suggesting longer-than-typical lead times. The preceding 16-month rising trend in the Indicator has yet to fully take hold in U.S. Industrial Production.

Editor's Note: Please note that this chart has been modified on the Y-axis to show the trend more easily.



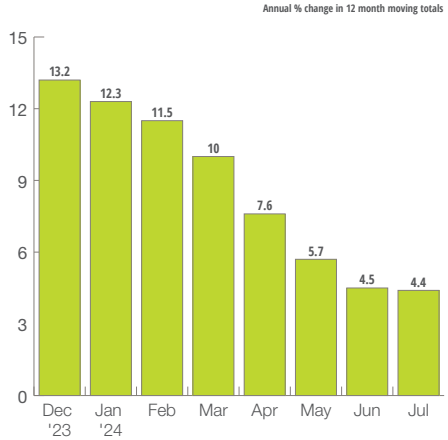
U.S. Industrial Production

- U.S. Industrial Production in the three months through August was 0.2% above the year-ago level.
- Lower-income consumers are struggling and interest rates have dampened capex, contributing to a general plateau in Production. Headwinds will linger in the near term.



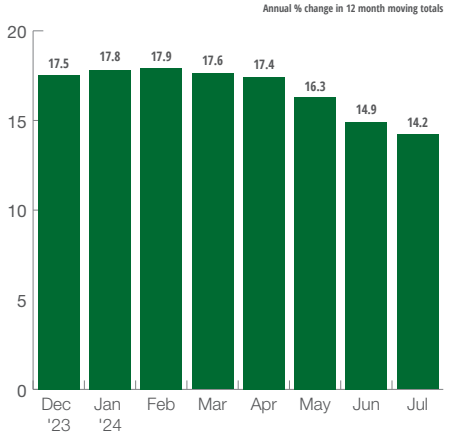
U.S. Private Nonresidential New Construction

- U.S. Private Nonresidential Construction in the three months through July totaled $187.0 billion, 4.4% above the year-ago level.
- Downside pressure from high interest rates will negatively impact Construction in 2025; the recent interest rate cut by the Federal Reserve will be a positive sign further out.



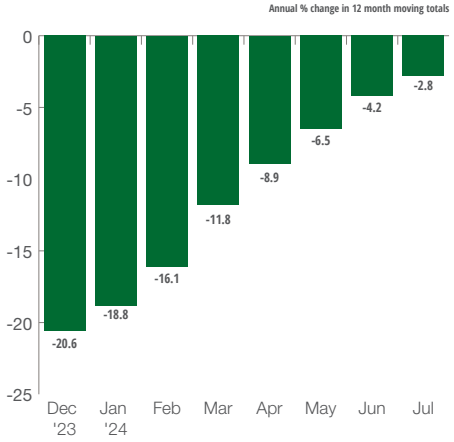
U.S. Total Public New Construction

- Annual U.S. Total Public Construction in July totaled $477.5 billion, 14.2% above the year-ago level.
- Public Construction is slowing in growth. This sector is less interest-rate-sensitive than the private sector but does face some downside pressure from weaker tax revenue.



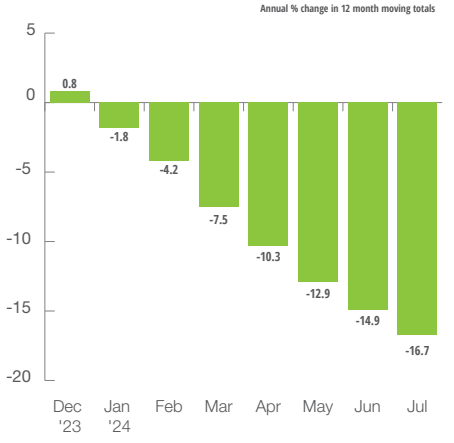
U.S. Farm Machinery Production

- U.S. Farm Machinery Shipments in the 12 months through July were 2.8% below the year-ago level.
- Weak agriculture commodity prices are a downside signal, while recently lowered interest rates are a potential upside.



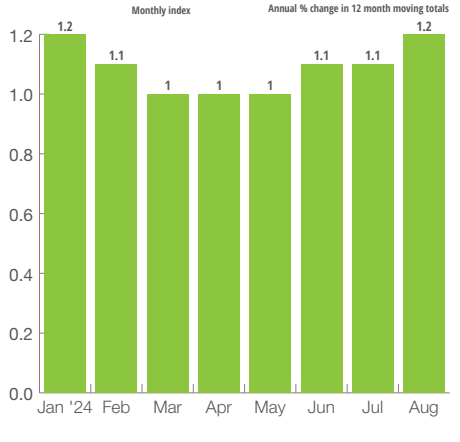
Europe Ag & Forestry Machinery Production

- Europe Agricultural and Forestry Machinery Production in the 12 months through July was 16.7% below the year-ago level.
- High energy costs in the EU are a likely downward pressure on Production as farmers grapple with rising costs.



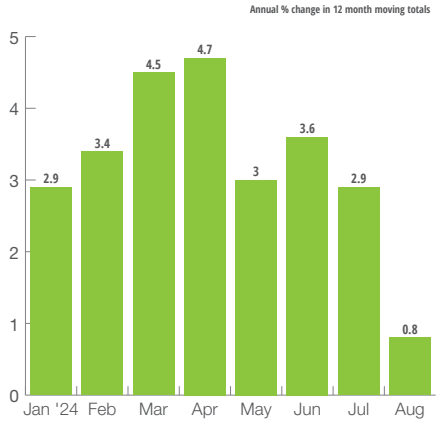
Europe Leading Indicator

- The Four Big European Nations Leading Indicator monthly rate-of-change rose in August but has been generally trending horizontally.
- Sluggishness in China's economy, a major trade partner for Europe, has been a downside but recent Chinese stimulus could help given Europe's nascent recovery.



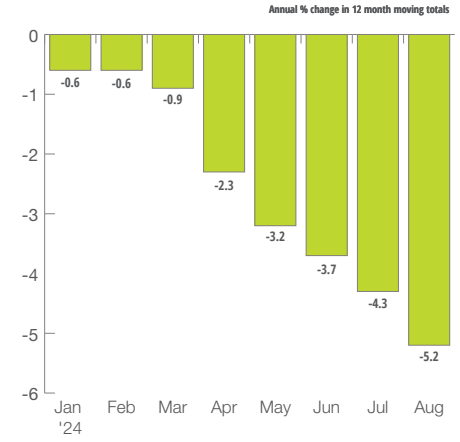
U.S. Heavy-Duty Truck Production

- Annual U.S. Heavy-Duty Truck Production in August was 0.8% above the year-ago level and is nearing year-over-year contraction.
- Rising wholesale trade will likely keep recession in Production mild.



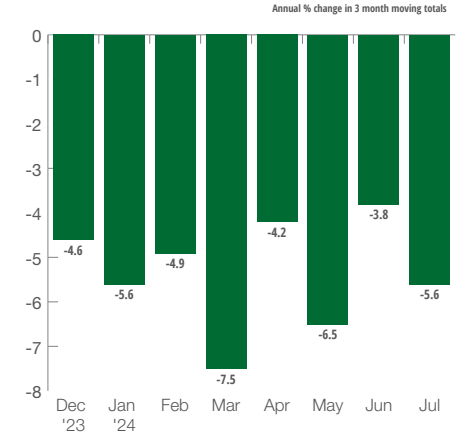
U.S. Mining Production

- Annual U.S. Mining Production in the 12 months through August was 0.4% above the year-ago level. Hard rock mining is declining while oil and gas extraction is rising.
- Quarterly Production is below year-ago levels, signaling that further downward pressure is likely.



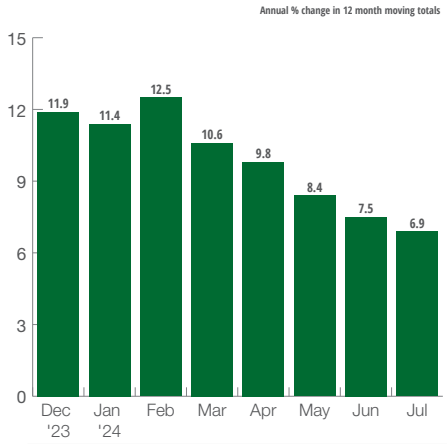
Germany Industrial Production

- Germany Industrial Production in the three months through July was 5.6% below the year-ago level.
- The Germany Motor Vehicle Production Index is down 10.8% over that same time, a drag on the industrial sector.



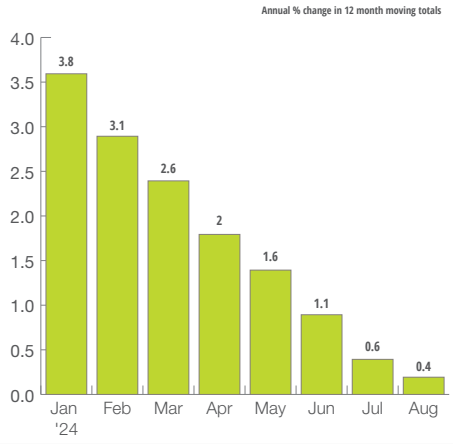
U.S. Construction Machinery, New Orders

- Annual U.S. Construction Machinery New Orders rose in July to $51.5 billion, 6.9% above the year-ago level.
- The recent interest rate cut by the Federal Reserve will have a long and lagged impact on New Orders.



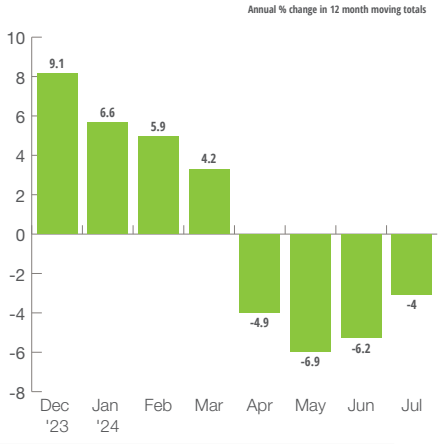
U.S. Mining & Oil Field Machinery Production Index

- U.S. Mining and Oil Field Machinery Production in the 12 months through August was 5.2% below the year-ago level.
- Mining companies remain conservative on capex given heightened uncertainty, sluggish macroeconomic data, and still relatively high interest rates. Recent upward movement in industry utilization rates is a nascent green shoot.



U.S. Defense Industry, New Orders

- Annual U.S. Defense Capital Goods New Orders in July rose and were 4.0% below the year-ago level. New Orders are in a recovery trend.
- Tensions continue to worsen overseas with no sign of cooling and the U.S. continues to send military aid to Ukraine. New Orders will likely continue to rise.



CONSTRUCTION, MINING INDUSTRY Mid-Term Outlook

The construction and mining industries are growing and much of it is happening outside the United States, which should make companies consider new strategies.

by Wilfried Aulbur, Giovanni Schelfi

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The mid-term outlook for the construction and mining industry up to 2030 is positive. Inflation-adjusted growth is projected at a compound annual growth rate (CAGR) of 4 and 1%, respectively. There are many drivers of this positive development.

Lower interest rates enabled by cooling inflation promise to impact commercial and residential construction positively, the latter supporting sales of compact construction equipment such as in the U.S.

Government spending is a significant factor in the development of the construction industry. This is driven by the regionalization of critical supply chains and considerable industry policy considerations. For example, In the U.S., it is happening via the Jobs Act, Chips Act and Inflation Reduction Act. In the EU, it is happening through the new Green Deal, are re-investing in infrastructure. Other nations, such as China, via the One Belt, One Road initiative, are leveraging infrastructure investments to ensure exports for their domestic industries while increasing global leverage. Countries like India, via the National Infrastructure Pipeline, also are investing in catching up with demand while positioning the country as a future manufacturing alternative to China.

India's investments are an excellent example of the rise of the Global South. Many emerging countries need infrastructure investments to build a more robust basis for economic expansion and job creation. However, this increase in demand is a mixed bag for many western original equipment

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manufacturers (OEMs). Western companies face competent Chinese competition due to cost sensitivity and differentiated customer requirements in Latin America, Africa and Southeast Asia. Chinese companies, facing economic hardship at home, are increasing their market presence in these geographies. Given significant trade relationships between many emerging markets and China, they often enjoy a "place of production" benefit.

Combined with aggressive pricing, an increased focus on aftermarket and market-adequate products augurs well for their future. Western players need to revisit their globalization strategies for emerging markets.

However, the strategic readjustment must also include home markets, as Chinese competition that builds scale in emerging markets can be a formidable foe at home. This is likely to be the case in Europe, where tariff non-tariff barriers towards Chinese products promise to be less stringent than in the US.

Industry trends to consider for the future

Electrification in construction equipment will not lead to significant penetration by 2030. We expect low to mid-single-digit penetration rates by 2030, driven by cities that require zero-emission vehicle (ZEV) -based construction projects within city limits. For ZEV penetration to be more prevalent in construction equipment, the solution's versatility has to evolve in line with battery performance and cost.

We do expect a significant focus on autonomous solutions to optimize worksite performance. Rather than a regulatory push, as is the case for electrification, these solutions often experience customer pull as they improve efficiency and reduce labor dependency at construction sites. A case in point is collision awareness and avoidance systems.

Another significant trend is the increased use and intensity of connected services. A better understanding of machine problems and a proactive, maybe even predictive maintenance approach improve fleet uptime while increasing parts sales for original equipment manufacturers. Connectivity also opens the door for fixed-rate maintenance contracts that enable the exploration of new business models for OEMs and fleets.

While construction equipment also finds significant applications in agriculture, the overall trends are different. The agriculture market will likely be subdued for the next few years. The COVID-19 pandemic and Ukraine war-induced commodity boom has led to a robust market in which farmers bought what they needed and wanted. Most farmers are now careful regarding purchases given a more challenging market environment and are postponing purchases.

The main driver for growth in the mining business is a combination of global GDP growth and declining ore grades, which require more equipment to move more material of lesser value. Regional trends vary quite a bit. Globally, a decline in coal at about 1% will be offset by around 2% growth in metals and minerals and is primarily focused on battery materials, copper and iron ore.

Dematerialization reduced material demand globally, albeit by less than 1%. The increasing prevalence of recycling, especially in steel (iron), aluminum, copper and battery materials, reduces the demand for new materials mined.

Autonomy and autonomous hauling solutions are well established in the mining industry and will continue to drive work site productivity gains by 2030. These work site productivity gains of 5 to 10% reduce the number of equipment needed, while electrification, e.g., of 240-ton haulage trucks, will require more trucks to handle the same load as frequent charging reduces uptime by 15 to 20% according to our total cost of ownership (TCO) models. However, as the overall impact of electrification remains low till 2030 with less than 2% penetration, the overall effect of electrification on equipment volumes is expected to remain moderate.

Higher growth in India, Indonesia, China and the Middle East will dominate the next several years. Africa also will continue to play a role, but similarly to the previous discussion on construction equipment, Western players will face competent Chinese competition in these emerging markets.

Three considerations for Western OEMs

Given the industry's moderate growth prospects and increasing global Chinese competition, Western OEMs and suppliers should consider:

- Companies should watch their costs while taking advantage of global growth opportunities and enable frugal growth.
- Prepare for a strengthening Chinese competition by:
- Understanding Chinese cost structures, strategies and ambitions
- Understanding customer needs in emerging markets
- Developing product and service offerings for these use cases
- Investing in service solutions to bind customers beyond the pure performance of their product
- Monitor Chinese technological progress and customer value solutions
- Continue to invest in worksite optimization solutions standalone and with partners.

The Chinese challenge is similar to the entry of the Japanese and Korean players on the global stage. Yet, China's scale and installed capacity dwarf anything the industry has seen. While it is not too late to prepare, Western OEMs and suppliers have no time to lose.

Dr. Wilfried Aulbur *is senior partner and global head and* ***Giovanni Schelfi*** *is a partner at Roland Berger LP.*

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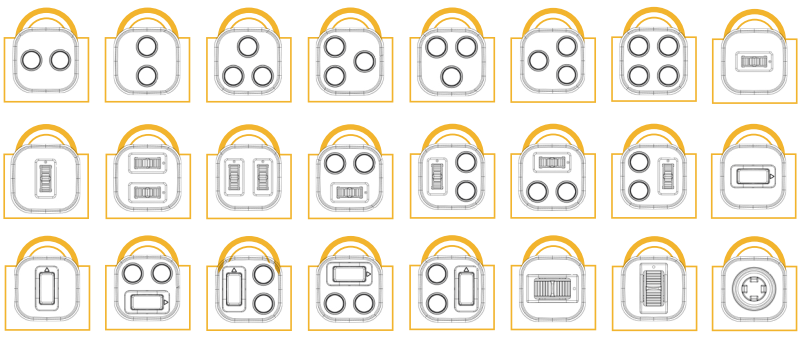

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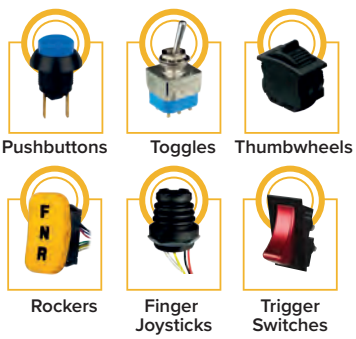

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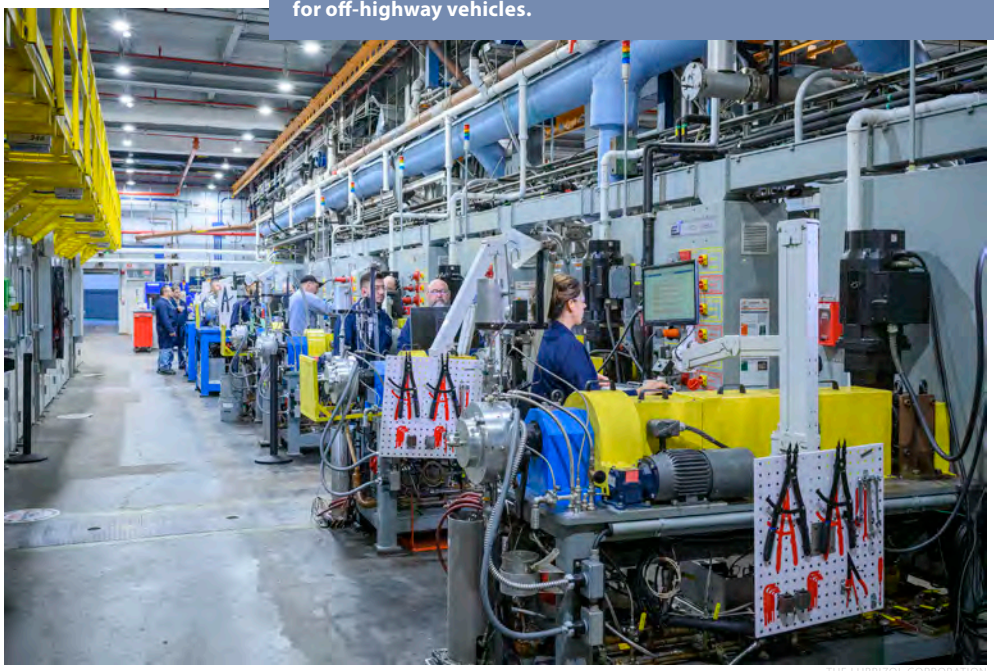
HIGH-PERFORMANCE FLUIDS Matter for Off-Highway Equipment

Developing high-performance fluids and new chemistries are critical for maintaining optimal durability, protection and reliability.

by Kevin Griffith

Figure 1: There is a lot of research going into fluid and lubricant research for off-highway vehicles.



THE LUBRIZOL CORPORATION

Several trends have begun to impact the off-highway equipment market in new ways over the past few years. For professionals in the field, it's worth examining their impacts.

A good example can be found in the agriculture industry in the United States where several high-level shifts in the market have had numerous trickle-down effects on industrial farming equipment and the fluids that enable them. Broad demand for food production continues to grow with the global population. Crops feed the population. Greater consumer demand means the need for greater crop yield.

In the United States, industrial farms are meeting these demands in an interesting fashion. Across the country, farmland by square mile or acreage is decreasing. There are fewer farms by number and an increasing number of larger farms focused on optimizing yield with highly efficient acreage use. In fact, it's estimated 42% of farmland is controlled by 2% of farms which make up the >5,000 acre category. Producing more with less is a major theme in the industry.

Because of this, major agriculture original equipment manufacturers (OEMs) have developed efficient, powerful new hardware to meet these needs. Larger engine sizes and torque requirements are now the norm to get more efficient work from a single tractor so they can harvest large areas in a short amount of time. This has major implications for the critical fluids that protect and enable the tractor's transmission, hydraulic systems and final drive gears at the tractor's axle.

Similar trends are impacting heavy-duty equipment in large scale construction and mining applications. Increasingly large equipment is performing more demanding work, necessitating higher and higher performance from hydraulic, transmission and final drive fluids.

"More with less," indeed, is becoming a trend not just in these industries, but everywhere off-highway equipment has a role to play.

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"More with less," indeed, is becoming a trend not just in these industries, but everywhere off-highway equipment has a role to play.

Such equipment will require advanced, high-performance fluids to meet their full potential. It's important to understand the importance of changing demands of such fluids, how next-level-performance is possible and why achieving such performance is so critical as industries continue to demand greater efficiencies in all applications.

Examining fluid performance requirements for today's equipment

Consider what's at stake for fluid performance. The average market value of machinery and equipment per farm continues to rise (almost 3x in the last 20 years). These are major investments for end users, and they must be protected — all the more reason to leverage premium fluids in every application.

Modern industrial tractors provide an instructive example of modern performance demands. In this application, a single fluid is used to protect three critical drivetrain components, as noted: The transmission, the hydraulic system and the final drive. Such tractors commonly have one sump that supplies fluid to each of these important areas. The challenge here is each of these applications can have conflicting performance requirements.

For example, traditional gear oils that might otherwise be used in a final drive system have trended toward lower and lower friction performance to enable greater machine efficiency. As a result, less resistance between the moving parts enables heightened power economy.

Because the same fluid in a large tractor application is also used throughout the transmission, a very specific level of friction performance is required as designed by the OEM. Friction plates in the transmission and wet brakes in the final drive must be able to grab and hold together to provide functionality, and they must do so at high levels. This can become a complicated ask, especially as torque loads continue to increase in larger and more powerful machines.

Those high torque levels, as well as larger gears within the transmission, also necessitate higher levels of wear protection from the fluid — perhaps its most important job. Indeed, OEMs are specifying new heights in wear protection. We are starting to see higher levels of wear performance requirements from major driveline suppliers for large equipment. Balancing these requirements with adequate friction performance has proved a challenge for fluid formulators.

There also are the needs of the hydraulic system to consider, as well. Important performance characteristics, like a hydraulic fluid's ability to maintain its designed viscosity throughout its service life, must also be balanced with friction performance and enhanced wear performance in such applications. Viscosity retention is important in low-speed, high-load applications where fluid flow is not robust enough on its own to create effective parts separation — if the fluid cannot deliver, wear performance can be further compromised.

Not all fluids found in the off-highway space must deliver this unique balance of performance. Construction and mining applications, for example, often see the use of dedicated fluids for hydraulic systems, transmissions and final drives, respectively. That said, many of the same demands still apply — machines are evolving to deliver more power and efficiency at higher torque levels, and fluid performance must continue to adapt. Meanwhile, there is desire from the end user to utilize a single fluid in each of these applications as a means to eliminate complexity in their operations.

The necessity of next-generation additive chemistry

To meet the changing needs of today's equipment, advanced additive chemistry must be deployed to deliver on increasing performance demands.

For instance, the heightened wear protection needs of modern driveline equipment that see higher torque loads have exposed some inadequacy in legacy chemistries. Zinc dialkyldithiophosphates (ZDDPs) have been one of the most reliable anti-wear additives in fluids and lubricants for many years, but they may have reached their limit in advancing off-highway driveline performance. Some ZDDPs used in off-highway additives (specifically aryl ZDDP) also have come under closer regulatory scrutiny — the European Union's REACH regulation for chemical substances has enacted harsher labeling for products containing such chemistry. As industries continue to move toward more environmentally-friendly and sustainable operations, new alternatives have become a necessity.

It's why advancing high-performance fluids with forward-looking additives to best enable off-highway equipment into the future is critical to satisfying modern demands. For example, through extensive testing and development, low-zinc anti-wear formulations have been designed to balance the range of performance needs of advanced off-highway equipment.

As critical equipment continues to evolve, it will be important that high-performance fluids are used across the board. OEM and industry specifications throughout the off-highway space will necessitate as much in the coming years as new needs are identified to best enable modern equipment to meet its full potential.

Fluids and lubricants are not just a component part of modern hardware operation — they must become technologically-advanced enablers in meeting the growing efficiency needs of the modern world.

Kevin Griffith *is a driveline product manager at The Lubrizol Corporation.*

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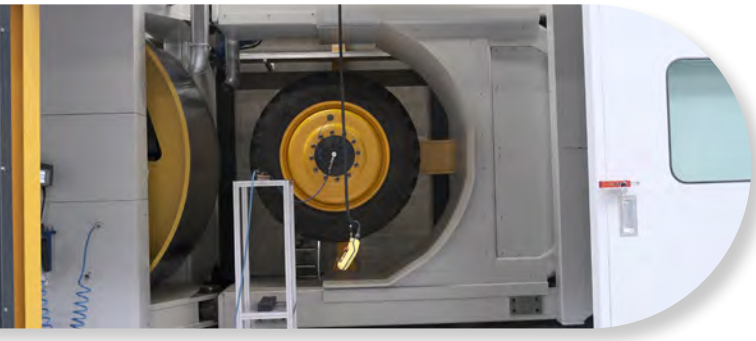

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The DIGITAL TRANSFORMATION of Heavy Equipment and Off-Highway Vehicles

The demand for smart, sustainable heavy equipment is rising and digital transformation is playing a key role

by Dale Tutt, Hendrik Lange

Figure 1: Digital transformation is critical to meeting the growing demands on the heavy equipment and off-highway industry for advanced vehicles that support efficient production of food, raw materials, and more.

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The demand for heavy equipment and off-highway (HE/OH) vehicles is growing. Heavy-duty machinery like agricultural tractors, excavators and haul trucks are critical for many industries and the sourcing of the raw materials needed to manufacture a variety of consumer and commercial tech products. The need for these vehicles is increasing as global urban populations rise and industrial customers and consumers demand greater capabilities in various products.

Meanwhile, new regulations and sustainability mandates require companies in all industries become more efficient, accomplishing greater productivity while using less energy and resources. Heavy equipment and off-highway original equipment manufacturers (OEMs) must innovate, delivering vehicles and equipment that are smarter, more connected and more efficient. Traditionally hydromechanical systems are being replaced with advanced software and electronics that can support core functions while also providing a platform for more advanced features and functionality now and in the future.

The next generation of heavy equipment and off-highway vehicles will be the most complex ever. Traditional approaches to vehicle development, manufacturing, and service will not scale to meet the demands of these vehicles, driving heavy equipment and off-highway OEMs to seek new methods that align with the growing need for innovation, agility and speed.

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Figure 2: Autonomous machines must navigate work sites and operate robotic components without human intervention but can deliver significant gains in productivity.

Business, tech trends for HE/OH manufacturers

There are a few challenges for HE/OH manufacturers as they navigate this industry. In addition to the transition toward software-defined products, HE/OH products must become more efficient and sustainable to meet various regulations and environmental targets. And while the need for innovation is high, manufacturers must be careful to keep pace without overspending on programs that will not deliver near-term value.

HE/OH manufacturers also are investing in electrification and autonomous driving and robotics to achieve a future of smart, efficient and high-value products. From a business perspective, these same innovative capabilities can provide opportunities to create new value-based business models that generate more stable high-margin revenue.

Electrification, alternative fuels drive gains in efficiency

Heavy equipment and off-highway industries are exploring electrification as a means of improving equipment efficiency and industry sustainability. Electrified powertrains, whether they're full battery electric or hybrid diesel-electric, have shown potential in several applications common to the HE/OH industries.

Battery electric vehicles (EVs) are already being deployed in high-load and low-range applications and in smaller vehicles like skid steers and small excavators. These applications are well-suited to the high torque and precision of electric motors. They also enjoy additional benefits of reduced noise, vibration and emissions producing a healthier and more pleasant job site.

Long-term cost of operation and ownership of these vehicles is often lower than their diesel counterparts.

Electric power delivery has also increased in viability thanks to improvements in the practices of HE/OH customers. In the agricultural sector, many farmers are reducing or eliminating soil tilling as a part of their growing practices, opting instead for direct seed drilling or minimal tillage approaches. By minimizing or eliminating the ploughing process, the average power required to sow a field is reduced. This reduction in average power demand means that battery-powered vehicles can operate longer on a single charge, ensuring the farmer

"HE/OH manufacturers also are investing in electrification and autonomous driving and robotics to achieve a future of smart, efficient and high-value products."

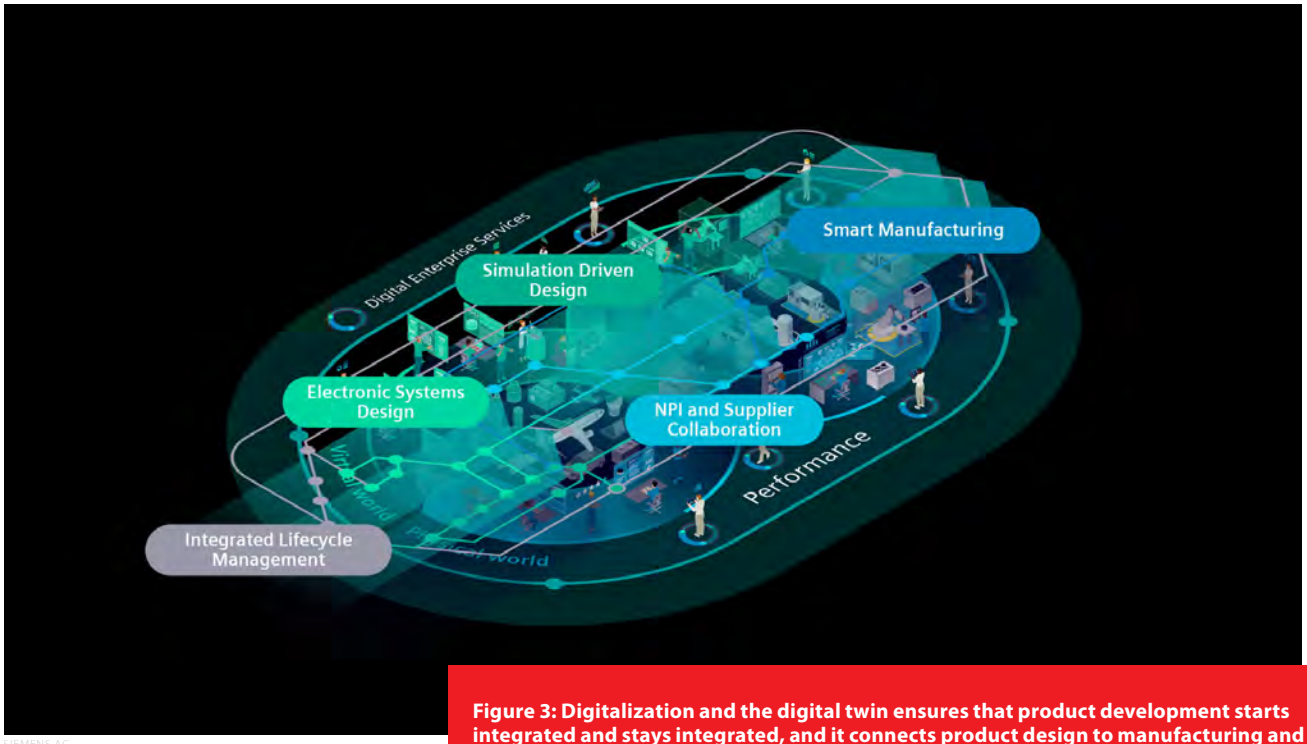

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Figure 3: Digitalization and the digital twin ensures that product development starts integrated and stays integrated, and it connects product design to manufacturing and service lifecycles.

can keep up with tight planting and harvesting schedules.

Many HE/OH OEMs also are developing equipment that can be powered by hydrogen and other alternative fuel types. These fuels can reduce combustion emissions and the overall carbon footprint of vehicles without imposing long refueling times. These alternative energy sources also offer different range and load characteristics, making them well-suited to different applications to battery EVs.

Some challenges prevent battery electric and alternative fuels from being a scalable solution in the near-term for all segments and applications. Charging time is the most salient drawback, particularly for remote job sites where high-quality, fast-charging connections are likely not available. Electrification also tends to increase the upfront cost of machinery. At the same time, reliable supply of alternative fuels remains a hurdle because fueling infrastructure and supply chains for alternative fuels is nascent.

Automation's future role in self-driving, autonomous robotics

In the longer term, HE/OH OEMs are focusing on the development of autonomous driving and robotics for farming, construction, mining and other heavy-duty applications. The development of an autonomous machine that can independently navigate and manipulate its environment is complex, requiring integrated systems of sensors, on board and cloud computing and precise actuation.

These machines face other unique challenges. Due to the low production volumes common to the industry, the cost of custom sensors and computer chips is more difficult to recoup. As a result, HE/OH OEMs often rely on off-the-shelf sensor and compute components to enable autonomous functionality, which places additional constraints on engineering and design.

Autonomous machines also may require greater object recognition abilities to that of a self-driving car. An autonomous sprayer, for example, would need to be able to distinguish between crops, harmful weeds and other non-crop plants that may be beneficial.

These OEMs, however, have the advantage of working in relatively controlled environments compared to dense urban environments or highways full of other drivers. An autonomous tractor or haul truck, for example, will only ever operate within a limited area, such as a crop field or quarry, which makes routing and navigation simpler. Even when moving to a new field or job site, these relatively small areas can be digitally mapped in detail, providing the autonomous system with accurate topological information to guide routing and navigation. With controlled, predictable routes, human operators' safety is easier to ensure.

Electrification, automation and the underlying shift toward software-defined vehicles and machinery also are being pursued in response to customer and regulatory demands, and to capitalize on new business opportunities.

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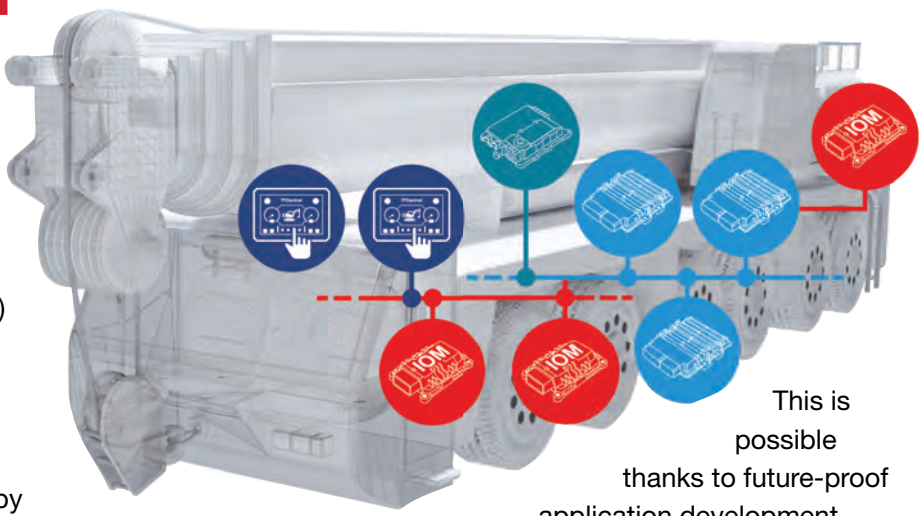

Machine manufacturers face the challenges of faster development and shorter time-to-market, while also having to meet stringent safety standards for all safety-relevant machine control functions.

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MATCH helps develop and maintain control systems across their entire lifecycle, from the design and development phase to redesigns of existing machines, machine parts, and functions. With MATCH, machine manufacturers can increase efficiency and speed up software development by up to 50%.

This is possible thanks to future-proof application development processes and TÜV-certified robust middleware that ensures quick implementation of safety functions. MATCH is based on the V-model, offering integrated test methods and validation for each part of the software development lifecycle. In addition, MATCH is multi-device capable and easily portable, as it supports Integrated Development Environment (IDE) open standards.

TTControl products with MATCH

The integration of HYDAC Software's MATCH into TTControl's solutions allows customers to benefit from easier programming of their embedded ECUs, updating their display visualization solutions, or enabling remote access to machine data.

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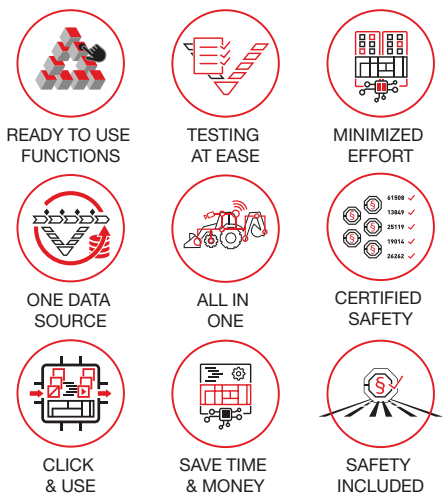

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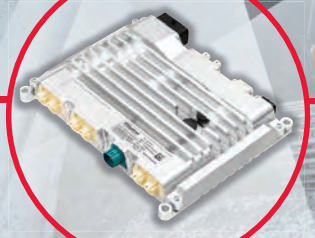

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Incorporating and scaling these technologies depends on the ability of companies to manage cost, overcome complexity in development and produce reliable and robust systems.

Digitalization as foundation for the future

Digital transformation of the entire lifecycle from design and engineering through to in-field service and maintenance can help OEMs design, produce and service the connected, smart, and reliable HE/OH vehicles and equipment their customers need.

Through the digital twin, HE/OH vehicle manufacturers can drive engineering activities that span multiple disciplines, domains or even lifecycle stages. Such an approach incorporates software, electrical, electronic and network domains into a holistic system-level development program. Requirements for the vehicle's mechanical, electrical, electronic, network and software systems can be defined and integrated at the earliest stages of development, ensuring domains are synced from the beginning.

As development progresses, the digital twin ensures engineering data stays in-sync and is available where and when it is needed, preventing miscommunications and guaranteeing decisions are made based on the latest information.

Advanced simulation tools also facilitate continuous verification and validation, promoting the optimal balance of multiple aspects of vehicle performance. When applied in automated scenarios, simulation can be used for design exploration, algorithmic decision-making, or to virtually execute a massive number of duty cycles for the certification of autonomous systems.

Digitalization also can extend into the manufacturing and service lifecycle for HE/OH vehicles, helping develop smart and flexible production systems and master mixed-model production in a complex global manufacturing ecosystem. HE/OH vehicles are either highly customized or even unique; often about 20 percent of the final configuration of a vehicle is specific to the customer. The digital twin helps companies create flexible and adaptable production systems that accommodate these unique configurations while maintaining high throughput.

The comprehensive digital twin also supports a closed loop between design, manufacturing and the product in use where data from throughout the lifecycle can be captured and turned into value for the OEM and their customers. Manufacturing data, such as

quality reports or scrap rates, and real-world product performance data can be leveraged to improve product designs and production systems. Real-world data also can be used to provide high-quality customer service and technical support as OEMs transition from machine vendors into solution partners.

By capturing live operational data, OEMs can provide customers with targeted and efficient diagnosis and repair services and even help prevent unscheduled downtime by anticipating issues and recommending interventions before they take a machine out of service. These capabilities will only become more important in a future of automated vehicles and machinery, as robust operational data can be analyzed with industrial artificial intelligence (AI) to guide the development of new software features and improve machine performance.

Digitally constructing the products of the future

Innovation in the HE/OH industry is being pursued to develop capabilities that will support construction, farming, mining and material handling sectors in a future in which efficiency, sustainability and productivity must be addressed simultaneously. As pressures mount, these companies are looking to transform for the future and enabling innovative designs in an industry characterized by low volumes, small margins and demanding applications.

The comprehensive digital twin will act as the foundation for the collaborative, integrated approach demanded by modern vehicles, bringing the mechanical, electrical, electronic and software domains together to design a complete system. In addition to improving data sharing between all stakeholders, the comprehensive digital twin facilitates the translation of that data into actionable insights that can help reduce cycle times, increase efficiency and improve market agility.

The result is a competitive advantage in meeting growing customer demands for greater performance and smarter features. It's also helping companies overcome the challenges of growing complexity, shifting workforces and the need for sustainable designs for HE/OH vehicles.

Dale Tutt *is vice president at industry strategy at Siemens Digital Industries Software;* ***Hendrik Lange*** *is the director of the heavy equipment industry at Siemens Digital Industries Software.*

Crawling Carrier Technology Innovations ACCELERATING

Crawler carrier technology plays a key role and their innovations can have a major impact in many different industries that uses off-highway equipment and vehicles.

by Eric Fatyol

PRINOTH LTD.

Figure 1: Crawler carriers are versatile enough for applications in off-highway construction, mining, utility infrastructure, oil and gas, environmental reclamation and more.

Crawler carriers play a crucial role in the ever-evolving world of off-highway equipment, from construction, to oil and gas, to utilities and far beyond. As these sectors face increasing pressure to improve efficiency, reduce environmental impact and enhance operator comfort, the crawler carrier market is experiencing a significant transformation. This article examines the current state of crawler carrier technology and explores areas where the industry can focus its efforts to meet the growing demands of the market.

How climate control goes beyond basic comfort

Climate control in crawler carriers has long been viewed as a luxury rather than a necessity. However, as we push the boundaries of where these machines can operate, from scorching deserts to frigid arctic environments, advanced climate control systems are becoming essential for operator comfort and machine performance.

Industry leaders are now incorporating sophisticated HVAC systems as standard features. These systems not only ensure operator comfort in extreme temperatures, but also contribute to increased productivity and extended work hours. For instance, in southern regions of the United States, where temperatures can soar, a well-designed climate control system can make the difference between a full day's work and frequent breaks due to heat exhaustion.

Some manufacturers with broad equipment offerings also are leveraging unique technologies developed for cold climate applications to enhance their crawler carriers' climate control capabilities. Features such as windscreen de-icing systems, which combine forced air circulation glass heated by embedded filaments, ensure clear visibility in cold and humid conditions.

Comfort and ergonomics is key to operator retention

As the skilled labor shortage continues to challenge the construction and off-highway industries, operator comfort and ergonomics have become critical factors in equipment design. The most advanced crawler carriers now boast cab designs that rival the comfort of high-end automobiles by featuring spacious interiors, ergonomic controls and superior visibility.

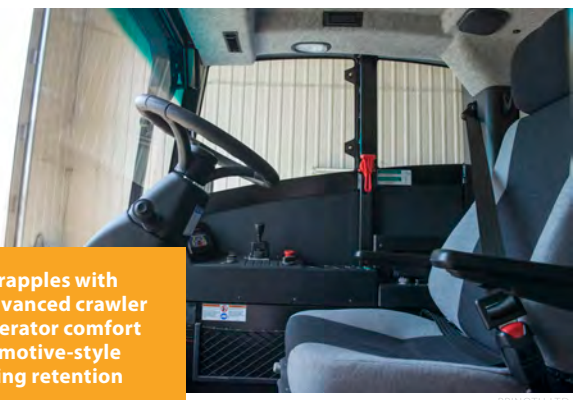

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Figure 2: As the industry grapples with skilled labor shortages, advanced crawler carriers are prioritizing operator comfort and ergonomics with automotive-style cabs and controls, enhancing retention and easing training.

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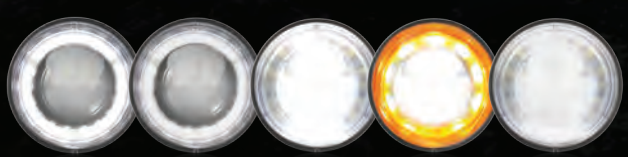

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One significant trend is the adoption of automotive-style controls, such as steering wheels and foot pedals, replacing the traditional levers found in many older models. This approach not only reduces operator fatigue during long shifts, but also shortens the learning curve for new operators.

Adjustable, air-suspended seats with lumbar support and ergonomically-designed armrests are becoming the norm. Some manufacturers are even introducing electric seats, allowing operators to find the optimal position.

Some modern crawler carriers are also equipped with cabs that meet rigorous roll-over protective structure (ROPS) and falling object protective structure (FOPS) standards, providing crucial protection for operators.

The emphasis on operator comfort, safety and wellbeing extends beyond the physical aspects of the cab. Noise reduction technologies, including improved insulation and engine placement, are creating quieter work environments, reducing operator stress and fatigue over long work hours.

Simplifying complex tasks

The complexity of operating heavy equipment has long been a barrier to entry for new operators. However, the latest crawler carriers are incorporating technologies that simplify operation without compromising capability.

One innovation is the introduction of automated systems for tasks that used to require significant operator skill.

Inclinometers with visual and soon audible alarms also are becoming standard, providing real-time feedback on machine stability and helping operators navigate challenging terrain safely. Some advanced models are even incorporating adaptive control systems that learn the characteristics of various attachments and optimize performance, reducing the need for manual adjustments.

Another area of focus is the interface between operator and machine. Touch-screen displays with intuitive, customizable interfaces, providing operators with clear, relevant information, are replacing traditional gauge clusters. These systems often include on-board diagnostics, which simplify troubleshooting and reduce downtime.

Enhancing safety and productivity

In the crawler carrier market, visibility is not just about operator comfort — it's a critical safety feature that impacts productivity. Leading manufacturers are redesigning cab structures to maximize visibility, with some models offering nearly 360-degree views of the surrounding area.

Large, panoramic windshields and floor-to-ceiling side windows also are becoming more common, as are sloped hood designs that improve forward visibility. These design changes not only enhance safety by reducing blind spots but also increase efficiency in tasks that require precise positioning, such as working near excavations or in tight spaces.

Fleet management's future in connectivity, telematics

Perhaps the most transformative trend in crawler carrier technology is the integration of advanced connectivity and telematics systems. These technologies are revolutionizing how equipment is managed, maintained and operated.

Some manufacturers offer telematics dashboards that enable fleet managers to monitor all vehicle operational data remotely. This includes real-time information on fluid levels, engine temperature, operating hours and much more.

These systems also allow fleet managers to virtually view all instrumentation the driver sees in the cab, providing unprecedented insight into machine operation and performance. This level of remote monitoring not only enhances operational efficiency but also aids in predictive maintenance, reducing downtime and extending equipment life.

Modern telematics systems also provide real-time data on machine location, operating hours, fuel consumption and performance metrics. This information allows fleet managers to optimize equipment utilization, schedule preventive maintenance more effectively and identify opportunities for operator training.

Data gathered from these systems also may help manufacturers design better products in the future. The engineering of newer generations of equipment will be predicated upon deep insight into operator and fleet managers behaviors, as well as equipment performance under different circumstances.

Some manufacturers are taking this a step further by offering remote diagnostics capabilities. These systems can alert maintenance teams to potential issues before they lead to breakdowns, reducing downtime and repair costs.

A holistic approach to crawler carrier advancement

The crawler carrier market is at a pivotal point in its evolution. The convergence of advanced technologies, changing workforce dynamics and increasing environmental concerns is driving rapid innovation across all aspects of machine design and operation.

It's clear the most successful crawler carrier companies will be those that take a holistic approach to advancement. This means not only incorporating the latest technologies, but also ensuring these innovations work together to enhance overall performance, efficiency and operator experience. For those manufacturers with broad market experience, cross pollinating technologies will continue to enhance vehicle design.

Eric Fatyol *is product manager, crawler carriers for Prinoth Ltd.*

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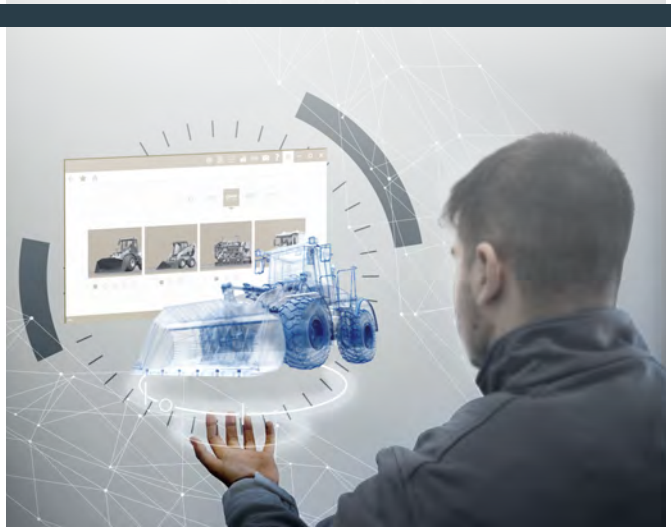

Tailored Diagnostics for Your Manufacturing Needs

In the rapidly evolving world of equipment and machine manufacturing, tailored diagnostic tools are essential. These tools provide precise diagnostics for specific systems and vehicles, streamline maintenance processes, and significantly reduce equipment downtime. For manufacturers, **custom diagnostic solutions** are vital for integrating electronic control systems, technical repair information, and warranty management procedures into a unified platform.

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Developing diagnostic hardware or software in-house can strain resources, leading to budget overruns and missed deadlines. Outsourcing diagnostic development mitigates these challenges, offering access to specialized talent and advanced solutions tailored to industry needs. Expert teams experienced in OEM guidelines deliver high-quality, efficient solutions, allowing companies to focus on core strengths.

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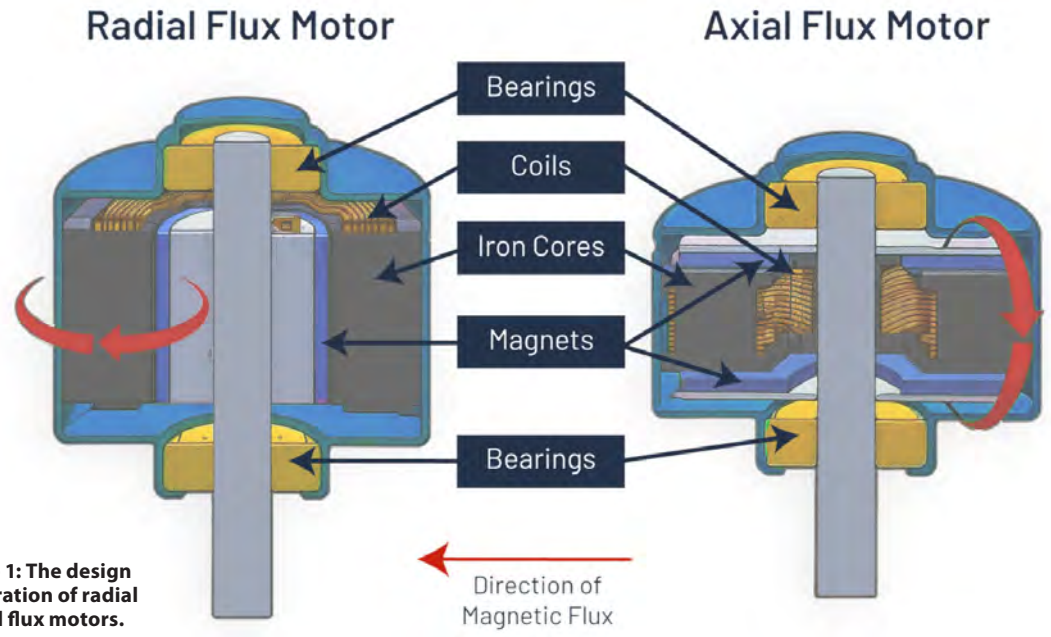

Figure 1: The design and operation of radial and axial flux motors.

AXIAL FLUX MOTORS

Moving to Mainstream Applications

Axial flux motors have several benefits that make them ideal for hybrid and electric applications.

by Matrishvan Raval

"As different vehicles have migrated from internal combustion engines to hybrid configurations or fully electric, the benefits of and demand for axial flux motors has increased."

Before a recent surge, axial flux motors were used in niche applications and premium automobiles. They were more difficult to engineer, and their manufacture was not scalable. This resulted in the benefits of these motors not being worth the cost except in higher priced vehicles where space was at a premium.

As different vehicles have migrated from internal combustion engines to hybrid configurations or fully electric, the benefits of and demand for axial flux motors has increased. With some manufacturers scaling their production, the cost is decreasing, as well. How are axial flux motors different, and what are their benefits?

Radial flux motor versus axial flux motor design

Based on the orientation of the magnetic flux, electrical machines can be classified into two categories (see Figure 1):

- **Radial flux.** The magnetic flux direction is radial to the axis of rotation
- **Axial flux.** The magnetic flux direction is parallel to the axis of rotation.

Radial flux motors are the most used motor today in vehicles and equipment. The cylindrical rotor moves inside a cylindrical stator. Because of the components (especially the coil layout) within a radial flux motor, it is much longer than an axial flux motor.

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Axial flux motors are flatter and are ideal in space-constrained applications like hybrid and electric vehicles and equipment.

A key determinant of torque and power delivery and electric motor efficiency is the magnetic field strength. Magnetic field strength will be higher if the magnetic flux path is shorter.

Field strength increases with diameter (D) of the rotor containing the magnetic material and reduces with the length (L) of the flux path. A higher D/L ratio provides a motor with a higher efficiency and a higher torque density.

Axial flux motor physics

For radial flux motors, the torque is proportional to the square of the diameter multiplied by the length. For an axial flux machine, the torque is proportional to the cube of the diameter and has no significant influence on the length.

Because of this, a smaller axial flux machine can provide more torque than a larger radial flux machine. If the equipment design requires high torque and power delivery and low motor weight and volume are necessary, an axial flux machine is the ideal choice.

Torque, power delivery and range benefits

A lower flux path means more torque, and depending on their size, some axial flux motors can provide two to four times more power at 50% less weight. While the smaller size is important for these motors to fit into electric or hybrid configurations, the decreased weight is also a major factor. In a vehicle, a 10% weight decrease means a vehicle range increase of 13% to 14%.

The decreased weight and increased range also result in lower total cost of ownership. In addition, the high-torque, low-speed operation of axial flux motors allows for reduced gearing ratio, further boosting the weight savings.

Axial flux motor topologies

Many topologies, features and design options are available for axial flux motors. Selection features include:

- **D/L ratio.** Short machines with large diameter.
- **Design modularity.** This has to do with stacking motors.

Design considerations include:

- Strong axial magnetic stator-rotor attraction force
- Mechanical design and manufacturing technology for production scaling.

Several topologies available are single-stator and single-rotor, double-stator and single-rotor, and single-stator and double-rotor.

However, a double-stator, single-rotor motor with internal permanent magnets is preferred because this configuration offers:

- Shorter machine length
- Effective winding cooling
- 96% efficiency.

Cogging torque

Cogging torque, the interaction between the permanent magnet motors and the slots in the stator, can be an issue with some axial flux motors. However, the double stator, single rotor has a low cogging torque or in many instances no cogging torque.

Design and testing

Using finite element analysis and computational fluid dynamics ensures proper operation and effective and efficient cooling. Cooling can be carried out primarily by a water-ethylene-glycol system or an oil-cooled system.

To ensure the motor has been designed with the latest technology, talk with the motor manufacturer and ask for the analysis data.

Exhaustive testing and validation to ensure performance, efficiency and durability are also important. Some test results to ask about include:

- **Dynamometer tests.** Evaluate torque, speed, power and efficiency under different operating conditions (also called dyno testing)
- **Thermal performance tests.** Assess the new motor's ability to operate reliably within the designed temperature parameters
- **Durability tests.** This helps evaluate a motor's longevity and resistance to mechanical stress, vibration and environmental factors
- **Test bench.** Validates the simulation results
- **Climatic, vibration, EMC and material suitability tests.** Evaluate their compliance with the standard to which they are built (for finished motors).

Use cases and applications for off-highway vehicles

Axial flux motors are ideal for hybrid configurations or fully electric systems of any vehicles or equipment, especially if space is limited. This includes:

- **Construction and mining equipment (excavators, wheel loaders).** They can be used to improve wheel traction, track traction, and ancillary functions such as slew and swing
- **Street sweepers.** They can be used to improve traction and sweeping implements
- **All-terrain vehicles.** They can be used to improve traction.

The increased use of axial flux motors

Axial flux motors are superior technology when compared to radial flux motors. They provide higher performance, leading to smaller, lighter, more efficient and more powerful motors. They also perform well in diverse applications especially when space limitations are a concern.

While costs for axial flux motor may have been a deterrent to their widespread use, manufacturers are now scaling their production. This scalability will decrease their cost and make them a more viable choice for vehicle and equipment manufacturers moving forward.

Matrishvan Raval *is product head for Turntide Technologies.*

STATE OF THE INDUSTRY 2024:

Optimism Ahead Despite Challenges

Six professional perspectives and predictions on the challenges mobile original equipment manufacturers (OEMs) faced this year and the optimism they have for the future.

by Chris Vavra

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Creating ERGONOMICS & EFFICIENT Operator Environments

A heavy equipment cab is essentially an office for its operator during very lengthy shifts. Consequently, it must be designed in a way that keeps the most-used function controls at the operator's fingertips, supports operator comfort, and considers sight lines and other machine safety concerns.

Ergonomic Armrests & Consoles

Everyone is built differently, and you must accommodate anyone who will run the machine, while still maintaining rigidity and creating a robust product. From plastics and ergonomics to custom electronic integration, every detail matters. Control layout and efficiency is a key aspect of armrest design. Primary machine function controls should be kept close at hand, like on a joystick or switch at the end of an armrest. To avoid overcrowding, however, controls that are used less can be moved further away from the operator to a post pillar or dashboard console. That is one of the numerous reasons why the operator's experience from when they enter the machine, to when they finish a shift, must be kept in mind in armrest design.

Fully Tested Populated Cabs

Expanding past an operator's primary controls, the overall cab design is full of details that impact productivity and experience. Again, put yourself in the place of the operator is key when designing a cab. Is the machine typically in extreme climates, greatly impacting the HVAC and filtration needs? What are the size restrictions on the cab in terms of available machine space? What safety certifications are required by the industry? If the machine will be in a populated work site and could therefore benefit from a radar or camera system? Working through all of these machine needs with an experienced partner will ultimately lead to an environment in which operators can be both comfortable and productive.

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There has been much uncertainty and concern in the mobile original equipment manufacturer (OEM) landscape in 2024. All of manufacturing, really, has been affected due to issues such as inflation, global conflicts, the 2024 Presidential Election and a changing market that is going more digital. The mobile OEM landscape has been very analog compared to some of its counterparts, but that is changing. Concepts such as digital transformation and the industrial Internet of Things (IIoT) are taking root, but what they can do are still an open question. So are issues with supply chain management, electrification, fleet management and more.

For this year's State of the Industry, *OEM Off-Highway* spoke with executive representatives across the equipment manufacturing landscape as they share their perspectives on today's most pressing challenges and what may be the horizon for manufacturing in the future.

Many challenges and headwinds for OEMs

While no two answers were the same, there were many different challenges OEMs faced and will continue to face. There are many challenges ahead and many are the result of lingering effects over the past few years.

Jason Steadman, business development manager – electrification – North America for Vanguard Commercial Power, said, "2024 has been a dynamic year for mobile original equipment manufacturers (OEMs), with numerous challenges impacting the industry. While supply chain disruptions are easing, they haven't disappeared and continue to delay production and impact the availability of essential components. Getting timely access to the specialized components needed for new technologies like electrification remains a real challenge."

Enrique Busquets, Director of Mobile Service & Aftermarket for Bosch Rexroth, said about the current market: "The mobile OEM landscape has been significantly influenced by the slowdown in agriculture, coming down from a peak in 2022, and construction, which has consequently resulted in elevated inventory equipment levels."

He also noted the challenges coming from all the uncertainty in the market relating to the market, the election and more, which has created general anxiety.

Electrification, or any power source or power generation, is going to be a major focus. Michael Lefebvre, manager of global marketing and product strategy for John Deere Power Systems, said, "OEMs must carefully assess the potential of each power source — from optimizing traditional internal combustion engines to exploring the possibilities of electrification, renewable fuels and even hybrid solutions."

Steve Hornyak, president and CEO at Turntide Technologies, spoke about the skills gap, which has been another issue plaguing many manufacturers regardless of industry.

"As in past years, finding and retaining talented, experienced engineers continues to be a challenge for component manufacturers and equipment and vehicle OEMs. Currently, the demand is outpacing available personnel."

Eric Alström, president at Danfoss Power Solutions, said about the market as a whole, "Market dynamics have been the most challenging aspect of 2024. Last fall, when we were talking to our customers and assessing what 2024 would look like, we were banking on a flat year compared to 2023."

That turned out to not be the case, though, Alström said, and the market has struggled.

"A number of factors have led to this. War in the Middle East and Ukraine plus geopolitical tension in Asia are among them, but the root cause is the high interest rates we see in many of our key regions."

Dr. Wilfried Aulbur, senior partner for Roland Berger, echoed these sentiments. "A key challenge of OEMs in 2024 was by and large a moderation of markets across the globe. The agricultural industry was significantly impacted as the buying bonanza induced by COVID, low interest rates and the war in Ukraine. The construction industry saw moderation in key regions, notably residential in China but also residential in Europe and the U.S., as homeowners adjusted to higher interest rates and a more difficult economic environment globally.

Overall optimism for the future of the mobile OEM market

Despite the challenges and headwinds the last couple years, there is a general sense of optimism. That was true even during the tough times. Many companies accepted there would be some turbulence, which has been a common theme this decade, as the world adjusted to a new reality thanks to the COVID-19 pandemic. Many practices considered common in manufacturing had to change and this has mostly been for the better as the status quo no longer became acceptable. The road ahead is a daunting one, but companies are prepared.

Lefebvre said, "2025 promises to be another dynamic year for the mobile OEM landscape. The industry won't be defined by a 'one size fits all' approach to power, but rather by a diverse array of solutions. We anticipate increased adoption of hybrid systems and battery electric solutions, all while advancements in internal combustion engines continue. OEMs will need to offer a range of options to meet the needs of various applications and customer preferences."

Aulbur said OEMs would do well to safeguard themselves from international competition, particularly that coming from China.

"2025 promises to be another dynamic year for the mobile OEM landscape. The industry won't be defined by a 'one size fits all' approach to power, but rather by a diverse array of solutions."

-Lefebvre

"The increasing presence of Chinese competition in emerging markets as well as Europe is a common theme across passenger cars, commercial vehicles and off-highway vehicles. Chinese players have made significant strides in key technologies such as batteries and smartphone-like user experiences in equipment that resonate with customers."

He added companies need to respond to this challenge through improved services, cost-competitive products and better internal processes.

One way is with digital transformation and the IIoT, which can help coordinate many devices at once and provide a clearer picture of what's happening through better automation. Busquets said about automation and its potential, "Automation within fleet management has enormous potential for OEMs, not only in system-wide monitoring and establishing operational standards, but in reallocating resources to different areas of the company. Tasks that perhaps took multiple operators previously can perhaps be done with one or two now thanks to strategic automation."

Steadman agreed. "I also think we'll see a growing emphasis on integrating smart technologies and connectivity. OEMs will increasingly leverage telematics and data analytics to optimize machine performance, improve efficiency and enhance the operator experience," he said, adding the data "unlocks a deeper understanding of equipment utilization, enabling optimized fleet management, remote diagnostics and proactive maintenance scheduling. This translates to increased efficiency, reduced downtime and improved profitability."

Hornyak also sees flexibility on the horizon as mobile OEMs continue to innovate. "An improved infrastructure is on the horizon," he said. "This will accelerate in 2025, opening the door for the increased adoption of hybrid and electric systems. Battery-electric power is the most accessible power alternative right now. The other zero-emission and lower emission options, including hydrogen, hydrotreated vegetable oil and other biodiesels, do not currently have much infrastructure and cannot currently scale geographically."

On the future, Alström said, "Working in such a cyclical industry, we are prepared for these down cycles, but the severity and length of this one took us a bit by surprise. So, 2024 has been tougher than expected. However, with the recent Federal Reserve and European Central Bank interest rate cuts, we're optimistic we will see improvement in 2025."

Mobile OEMs may have been through a lot the last few years, but they have proven their resilience and their ability to innovate. There have been tough times, but the general optimism and hope for the future remains, partly because many of these companies and workers have seen a lot already. They're hopeful they have weathered the storm for a better tomorrow.

STATE OF THE INDUSTRY PANELISTS

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Statement of Ownership, Management, and Circulation
(Requester Publications Only)

1. Publication Title	2. Publication Number	3. Filing Date
OEM Off-Highway	752-770	September 15, 2024
4. Issue Frequency	**5. Number of Issues Published Annually**	**6. Annual Subscription Price**
January/February, March/April, May/June, July/August, September/October, November/December	6	Free to Qualified Subscribers

7. Complete Mailing Address of Known Office of Publication (Street, City, County, State, and Zip+4)
IRONMARKETS
201 North Main St., Ste 350
Fort Atkinson, WI 53538-1807

Contact Person
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8. Complete Mailing Address of Headquarters or General Business Office of Publisher
IRONMARKETS, 201 North Main St., Ste 350, Fort Atkinson, WI 53538-1807

9. Full Names and Complete Mailing Addresses of Publisher, Editor, and Managing Editor

Publisher (Name and Complete Mailing Address)
Sean Dunphy
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10. Owner *(Do not leave blank. If the publication is owned by a corporation, give the name and address of the corporation immediately followed by the names and addresses of all stockholders owning or holding 1 percent or more of the total amount of stock. If not owned by a corporation, give the names and addresses of the individual owners. If owned by a partnership or other unincorporated firm, give its name and address as well as those of each individual owner. If the publication is published by a nonprofit organization, give its name and address.)*

Full Name	Complete Mailing Address
ACBM, LLC, DBA IRONMARKETS, Ron Spink, CEO	201 N. Main Street, Ste 350, Fort Atkinson WI 53538-1807

11. Known Bondholders, Mortgagees, and Other Security Holders Owning or Holding 1 Percent or more of Total Amount of Bonds, Mortgages or Other Securities. If none, check here. ☐ None

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12. Tax Status ***(For completion by nonprofit organizations authorized to mail at nonprofit rates). (Check One)***
The purpose, function, and nonprofit status of this organization and the exempt status for federal income tax purposes:
☐ **Has Not Changed During Preceding 12 Months**
☐ **Has Changed During Preceding 12 Months**

PS Form 3526-R Facsimile, July 2014

13. Publication Title	14. Issue Date for Circulation Data Below
OEM Off-Highway	July/August 2024

15. Extent and Nature of Circulation			Average No. Copies Each Issue During Preceding 12 Months	No. Copies of Single Issue Published Nearest to Filing Date
a. Total Number of Copies (net press run)			13,969	10,367
b. Legitimate Paid and/or Requested Distribution (By Mail and Outside the Mail)	(1)	**Outside County Paid/Requested Mail Subscriptions stated on PS Form 3541.** (Include direct written request from recipient, telemarketing and Internet requests from recipient, paid subscriptions including nominal rate subscriptions, employer requests, advertiser's proof copies, and exchange copies.)	11,745	8,580
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	(3)	**Sales Through Dealers & Carriers, Street Vendors, Counter Sales, and Other Paid or Requested distribution Outside USPS.**	36	1
	(4)	**Requested Copies Distributed by Other Mail Classes Through the USPS.** (e.g. first-Class Mail)	0	0
c. Total Paid and/or Requested Circulation [Sum of 15b(1), (2), (3), (4)]			11,781	8,581
d. Nonrequested Distribution (By Mail and Outside the Mail)	(1)	**Outside County Nonrequested Copies stated on PS form 3541.** (include sample copies, requests over 3 years old, requests induced by a premium, bulk sales and requests including association requests, names obtained from business directories, lists, and other sources)	1,482	1,222
	(2)	**In-County Nonrequested Copies stated on PS form 3541.** (include sample copies, requests over 3 years old, requests induced by a premium, bulk sales and requests including association requests, names obtained from business directories, lists, and other sources)	0	0
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	(4)	**Nonrequested Copies Distributed Outside the Mail** (include pickup stands, trade shows, showrooms, and other sources)	130	6
e. Total Nonrequested Distribution (Sum of 15d (1), (2), and (3))			1,613	1,228
f. Total Distribution (Sum of 15c and e)			13,393	9,809
g. Copies Not Distributed			576	558
h. Total (Sum of 15f and g)			13,969	10,367
i. Percent Paid and/or Requested Circulation (15c / 15f x 100)			88.0%	87.5%

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PS Form 3526 -R Facsimile, July 2014

Statement of Ownership, Management, and Circulation
(Requester Publications Only)

16. Electronic Copy Circulation	Average No. Copies Each Issue During Preceding 12 Months	No. Copies of Single Issue Published Nearest to Filing Date
a. Requested Electronic and Paid Electronic Copies	5,189	5,329
b. Total Requested and Paid Print Copies (Line 15C) + Requested/Paid Electronic Copies (Line 16a)	16,970	13,910
c. Total Copy Distribution (Line 15F) + Requested/Paid Electronic Copies (Line 16a)	18,582	15,138
d. Percent Paid and/or Requested Circulation (Both Print & Electronic Copies) (16b divided by 16c X 100)	91.3%	91.9%

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17. Publication of Statement of Ownership for a Requester Publication is required and will be printed in the November/December issue of this publication.

18. Signature and Title of Editor, Publisher, Business Manager, or Owner **Date**

Ron Spink, CEO 9/15/2024

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Turning a motor grader into five tools: ELEVATING GRADER ATTACHMENTS

Elevating graders adapted to motor graders in the 1950s, excelling in excavation tasks and material handling with belt improvements.

by Thomas Berry

The original elevating graders (EGAs) were drawn by stock, and tractor-drawn elevating graders were used into the 1940s before being rendered obsolete by advances in belt loader and scraper technology. However, the idea of the EGA experienced a revival in the 1950s and early 1960s as the concept was adapted to motor graders.

The majority of EGAs were mounted to the motor grader's frame in place of the circle and blade, and were designed to be more or less easily detached and reinstalled as needed. Jebco estimated 40 hours for initial installation, and eight for subsequent removal. In contrast, the Austin-Western Plainsman was pulled behind the motor grader, and the Rivinius R300 Multi-Purpose Loader was a force-feed loader pulled by a motor grader.

Most EGAs could be used for many tasks, including excavation, embankment placement from roadside ditches, stockpile aeration, window removal, construction of citrus orchard planting mounds, and stripping of broken asphalt pavement. Most were powered from the parent's PTO, and side-discharge EGAs required right-angle linkages to convey the power from the rear to the middle of the parent (Figure 1). Cutting discs were most often 30 inches in diameter, with larger parents getting 32- or 36-in. discs, and an EGA's maximum digging depth was typically the diameter of the disc.

The most common belt width was 36-in. wide, smooth and on flat rollers. Jebco used a troughed belt, giving up to 30% more carrying capacity while preventing load slippage and keeping the load centered on the belt.

The belt was mounted in a carrier frame, from 16 to 30 ft long for side-discharge EGAs, which could be folded for transport and storage so that the upper section was vertical. Larger parents could handle larger discs and longer carriers, increasing discharge height without increasing the conveyor angle for the most efficient loading. Faster belt speed than the norm of 450 ft per minute helped, as well.

The output varies with ground and terrain conditions. Of the known manufacturers, L-W and Jebco provided the most comprehensive figures for estimating an EGA's output. The specifics vary, but a good example was given for the 1956 model offered for Cat No. 12 and Adams/L-W 550 and 660 parents. Equipped with a 22-ft carrier set to a 10-foot discharge height and with the parent in first gear, it could cast 700 to 1500 cubic yards or load 400 to 800 cubic yards per hour in good ground conditions. ■

Thomas Berry is an archivist and editor with the Historical Construction Equipment Association (HCEA). The Historical Construction Equipment Association (HCEA) is a 501(c)3 nonprofit organization dedicated to preserving the history of the construction, dredging and surface mining equipment industries. With over 3,500 members in a dozen countries, its activities include operation of National Construction Equipment Museum and archives in Bowling Green, Ohio; publication of a quarterly magazine, Equipment Echoes, from which this text is adapted, and hosting an annual working exhibition of restored construction equipment. Individual annual memberships are $45 within the U.S. and Canada, and $65 elsewhere. HCEA's next International Convention and Old Equipment Exposition will be Sept.18-20, 2025, at the National Construction Equipment Museum in Bowling Green, Ohio. HCEA seeks to develop relationships in the equipment manufacturing industry, and offers a college scholarship for engineering students. Information is available at hcea.net or by calling 419-352-5616 or emailing info@hcea.net.

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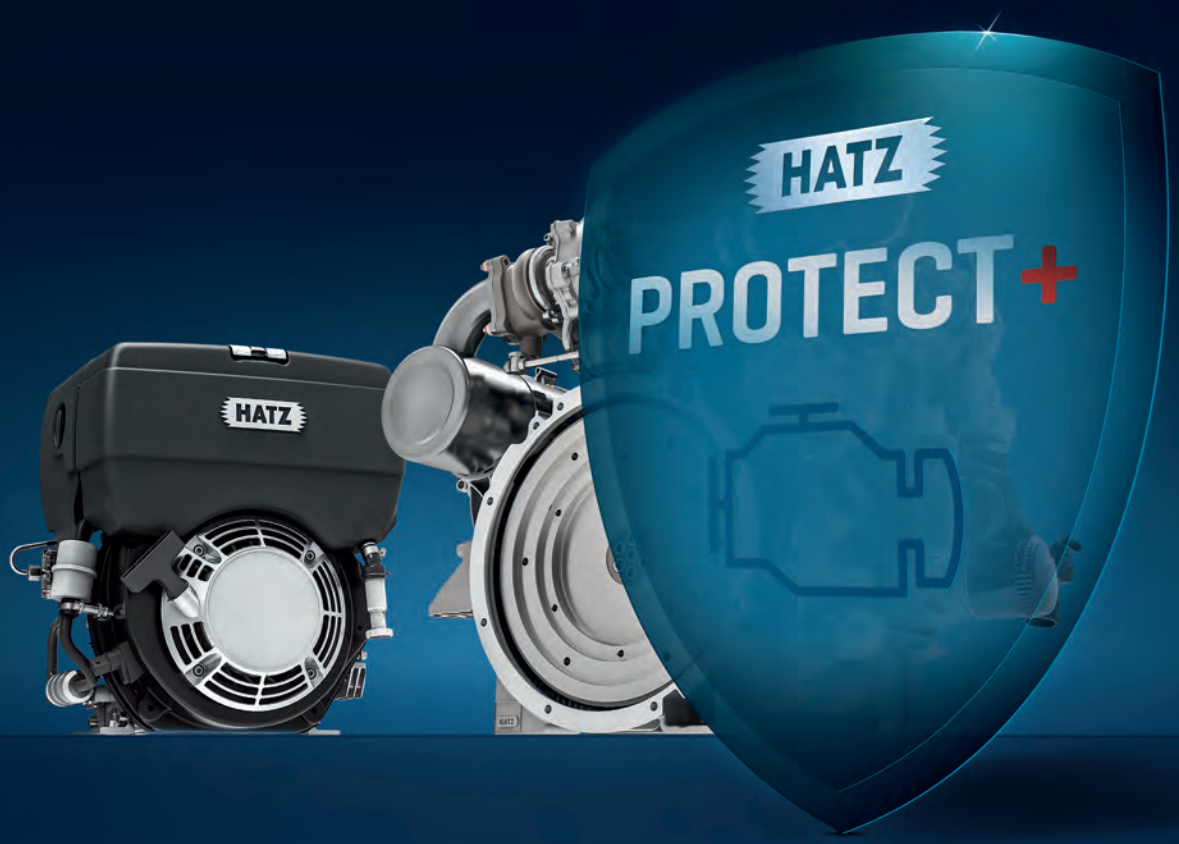

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