



Improving Wheel Loader Efficiency, Productivity and Regulatory Compliance with Integrated Systems



ENGINEERING YOUR SUCCESS.

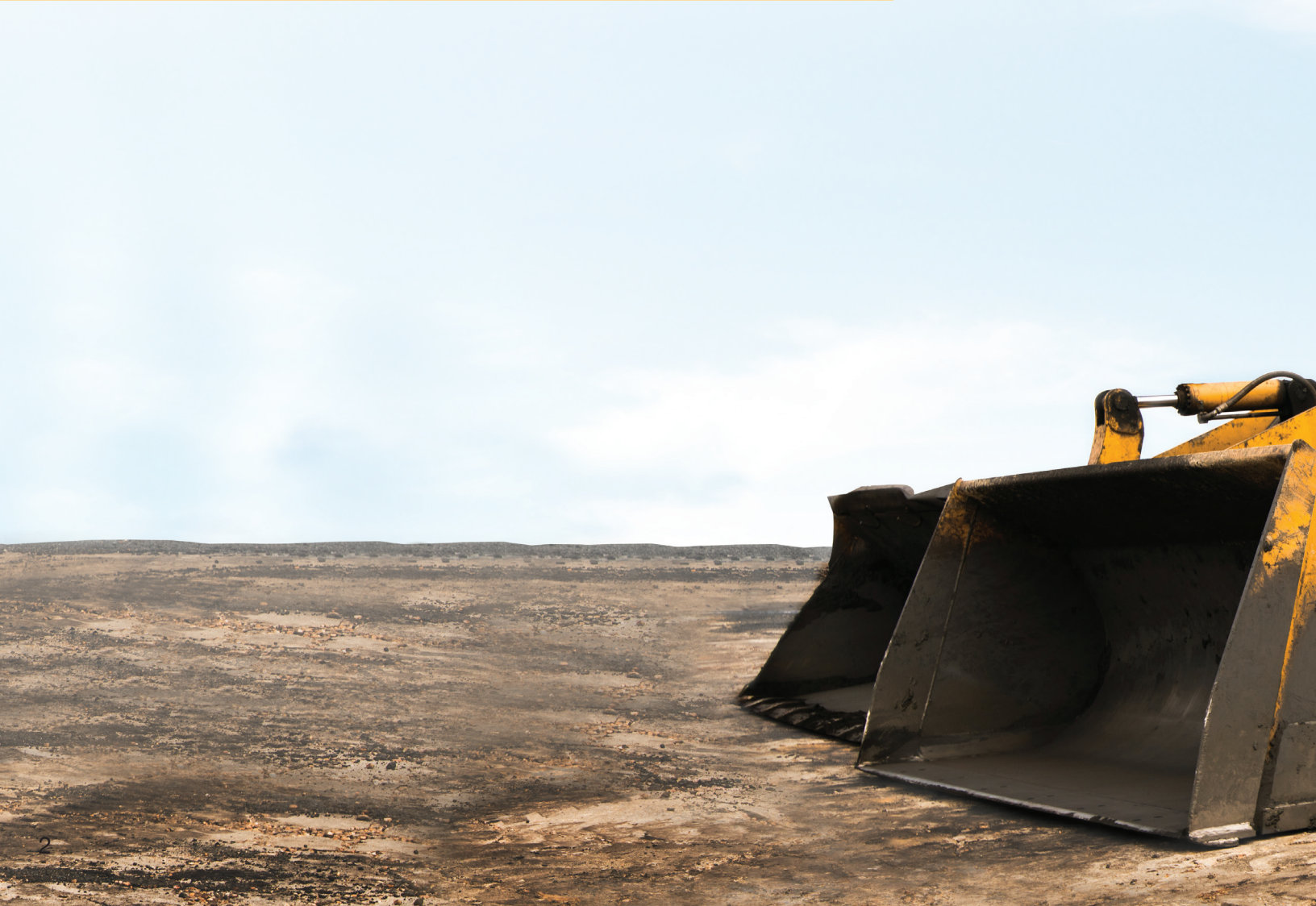
Contents

- Introduction**..... 3

- Challenges**
 - Regulatory and Certification Issues..... 4
 - Efficiency and Productivity 4
 - Non-Integrated Systems 4

- Innovations**
 - IoT and Sensor Integration 5
 - Engine Power Management and Fuel Efficiency 6
 - Electrification 7
 - Steer By Wire..... 7
 - Operator Comfort 8
 - Noise Reduction Solutions 9

- Conclusion** Back Page



Introduction

The construction market reported overall growth throughout 2019, despite the challenges of cost pressures, labor shortages and fixed-bid projects that will continue to impact construction equipment makers and owners.¹ Overall, the industry must focus on mitigating these challenges and driving trends that will improve operations and deliver competitive advantages for construction companies. Advancements in digitalization and connectivity offer opportunities for equipment makers to help overcome growing challenges due to regulatory issues.

Construction equipment can play a significant role in driving the industry forward and providing advanced solutions that enable growth. This paper explores construction industry challenges and innovations as they relate specifically to wheel loaders. Wheel loaders are key pieces of equipment that keep construction sites productive and may edge out other multi-function equipment in purchase preference if they are able to meet the needs of users for performance and price.



Challenges

Regulatory and Certification Issues

Today, OEMs designing wheel loaders are facing more redundancies and increased pressure for safety certifications than in the past. A safety integrity level, or SIL, measures performance required for a safety instrumented function based on IEC 61508 standards and used for compliance with ISO 26262, a functional safety standard for road vehicles.² While most in the industry are working with SIL2 solutions, there is a push toward SIL3. As is the trend in the industry, Europe is leading the charge. However, some U.S. companies are asking for the same levels for their equipment, particularly those who sell wheel loaders in both the U.S. and European markets. Systems within the wheel loader may be self-certified by the OEM for their SILs and there must be documentation to support it.

Regulations specifically as they relate to engines impact wheel loader operation in a variety of areas, including overall fuel efficiency, hydraulic systems, power management and noise production. Using a tiered approach to reduce emissions, the EPA limits diesel engines to near-zero levels for nitrogen oxides and particulate matter emissions. Tier 4 is the current standard impacting diesel engines for wheel loaders and other construction equipment. To accomplish large reductions in emissions, construction equipment manufacturers are tasked with developing technology that will produce the power and performance their customers need while adhering to the standards.³

Regulatory challenges can also extend to local ordinances that impact construction, such as noise ordinances that limit working hours.

Efficiency and Productivity

Design engineers and equipment owners face a delicate balance with wheel loaders between efficient cycle times, operator comfort and machine wear and tear.

Construction managers are feeling financial pressure from shrinking construction project timelines in the forms of penalties or bonuses. Demand continues to be strong for wheel loaders and other equipment that offer greater machine utilization that will help them

avoid time-bound penalties or earn early completion bonuses. Companies are investing time and resources into fleetwide management in order to understand, as well as optimize, uptime and utilization.

Equipment purchasing trends in construction also show a beginning preference toward purpose-built equipment such as mid-size wheel loaders in place of more multi-function equipment like backhoes.

Non-Integrated Systems

Related to productivity is equipment performance for wheel loaders. Non-integrated systems continue to be a pain point in the industry as the lack of integration among the many systems incorporated into wheel loaders impacts performance as well as overall ease of use and efficiency. Electronics open

the door to performance improvements for the full range of loaders in the construction market. New wheel loader models are expected to have integrated systems and electronic features that will help construction managers optimize their use on jobsites.

Innovations

IoT and Sensor Integration

Heavy equipment with embedded sensors and internet connectivity delivers value to manufacturers and fleet owners, through the constant collection and data analysis on usage, maintenance needs, downtime and more. Industry leaders are turning to IoT solutions to sense and adapt, improve operational visibility, address regulatory and compliance requirements, and respond to competitive pressures. In 2017, \$235 billion was spent on the combined IoT market, according to a Bain & Company report.

Although off-road mobile equipment IoT systems have their roots in telematics, most equipment manufacturers have begun to offer connected equipment that takes it a step further with IoT solutions that recommend or notify equipment operators on how to maximize performance and longevity.⁴

Parker offers a Mobile IoT system that is a digital integrated solution which connects hardware, software and asset management specifically designed for off-road equipment, delivering real-time, end-to-end operational information for wheel loaders. Parker's solution provides unique and valuable features for OEMs including:

- A simple user interface
- Plug-and-play configurability
- Implementation support
- A high level of customization
- Enhanced connectivity
- Fleet compliance and warranty reporting
- Over-the-air updates
- Flexible and future-oriented framework
- Service plan options⁵



Pressure, temperature and position sensors are just a few of the sensing technologies that should be incorporated into wheel loader designs for both IoT, safety, precision and overall system integration. The complex mechanical, electronic and hydraulic systems used by mobile equipment, when supported by digital ecosystems, are ushering in a new era of mobile solution innovation. Sensor solutions to consider integrating into wheel loader design include:

- Universal tilt sensors that detect and communicate the angle of tilt for more precise operation⁶
- Ferrous proximity sensors which detect nearby ferrous metal without contact which can enable home, extend and retraction or act as limit switch and safety interlock triggers⁷
- Accelerometer and inclinometer inertial sensors which can indicate acceleration or level positions⁸
- Rotary position sensors that use solid state, Hall Effect, non-contacting technology for position, height and angle sensing⁹
- Compact pressure sensors with thin-film technology and high-pressure capability to monitor high- and low-pressure system functions¹⁰

In its current state, IoT for wheel loaders focuses on prognostic and diagnostic data that enables predictive and preventative maintenance. By keeping wheel loaders running at peak performance, designers can reduce or eliminate unexpected downtime for their customers and help enable safer operation.

Engine Power Management and Fuel Efficiency

To comply with emissions standards, engine power management is an extremely important wheel loader design consideration. One strategy is redesigning hydraulic circuits from traditional fixed displacement gear pump solutions to a system that can more effectively make use of the engine power. An example of this is Parker's P1 series of mobile pumps that were developed specifically for OEM mobile applications.¹¹ When combined with Electronic Displacement Control, compact pumps can allow the equipment to operate at peak performance. In one application, Parker's P1 M pump with EDC, when encountering varying loads and running multiple functions simultaneously during operation, was able to increase the effectiveness of the engine's power by managing the pump output based on the engine power available and where the power was needed.

Mobile directional control valves with load-sensing technology can offer flexibility in system structure for both simple and advanced hydraulic systems. Parker's L90M valves can be optimized for their specific performance-enhancing functions in wheel loaders.¹² In addition to boosting hydraulic system performance, valves like these can use wheel loader engine power better.

Compact components are not limited to pumps or valves either. Fuel efficiency receives a boost when overall wheel loader weight is reduced. Design engineers can look to balance size and weight reductions in wheel loaders with performance requirements. Efficiency at a component level can include specifying smaller outside diameter and lighter weight hoses that can provide the same pressure and flow as traditional hoses.

Specifying hydraulic hoses like Parker's GlobalCore hoses, which are specified by working pressure rather than construction. The hoses are designed, built and tested to the ISO 18752 standard, simplifying specification for OEMs and end users by providing a comprehensive family of products for the most commonly used constant working pressure classes.¹³ Their high performance with lighter weight can contribute to overall wheel loader weight reduction.

Fuel efficiency receives a boost when overall wheel loader weight is reduced.

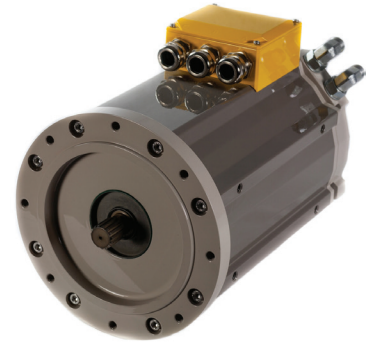


Electrification

Wheel loaders are considered by many to be the modern day work horse. Whether it is a compact machine used for landscaping and agriculture or a large machine working at a quarry site, the demands of increased efficiency and reduced emissions have to be addressed by OEMs. Fully electric or electric hybrid machines are being introduced to address these performance demands. Compact loaders, with reduced noise and emission capability, are allowing these machines to be used in expanded applications where these are critical factors. The application of electrification hybrid solutions on large machines is providing increased operating efficiency improvements while obtaining optimum fuel efficiency with distributed power providing the controls demanded. The technology and applications associated with these machines is gaining momentum and, in the future, will be expanded no doubt to other platforms.

Parker's Global Vehicle Motor (GVM) range of electric motors offers OEMs and end users the appropriate solution for all machines from compact to production machines. High power density, compact design combined with the highest efficiencies in the market provides the key. Introduction of electric solutions

allow the efficiency recovery and storage of energy which would previously be wasted. Parker offers a wide range of motors with up to over 400kW of power. With a variety of sizes, lengths and voltages up to 650V each application can be uniquely engineered to maximize a machine's performance.



The design of the GVM means that it can be used as a motor or a generator. This feature facilitates efficient system energy recovery whether from smart system design or braking solutions. This can provide a means of reducing expensive battery costs, extend the range between charges reduce overall machine operation costs.

With proven performance in a wide range of applications the GVM should be considered for application when looking for improvements in system efficiency, noise free operations and compact design.

Steer By Wire

Steer-by-wire is one innovative solution moving towards automation that has been developed with SIL certification and documentation in mind. While self-driving construction machines are the long-term goal, steer-by-wire is the clear trend for the construction industry of today. Steer-by-wire removes the need for heavy, complex steering columns. Parker's SBW110 proportional, load sensing, pre-compensated mobile valve optimizes steer-by-wire systems

deployed on mobile machinery. This means easier installation and reduced noise levels for the driver, making the cab a safer, more ergonomic place to work. By simply using a pump oil supply, tank connection and electric signal, the flow from the SBW110 valve work ports is able to control the steering function. The valve is characterized by class-leading performance for robustness, control precision and energy efficiency.¹⁴

Operator Comfort

Enhancements to operator comfort continue to grow as a priority for all heavy equipment OEMs and owners. With ergonomics, the goal is to create workplaces and tools that fit the people who use them, while increasing on-the-job efficiency and reducing risk of injury. According to Dr. Christine Branch, director of the Office of Construction Safety and Health for the National Institute for Occupational Safety and Health, “Ergonomics for construction workers plays an important role in reducing injuries. Many construction workers often work in cramped spaces, have awkward postures, carry heavy materials, and are exposed to vibration from tools and equipment. These exposures can result in musculoskeletal disorders, back injuries and other adverse health effects.”¹⁵

For wheel loaders, ergonomics is often approached in general cab design elements such as seats and handheld controls. These approaches are helpful to improving operator comfort, but OEMs can further improve comfort in wheel loaders by integrating even more in-cab improvements as well as improvements outside of the cab that impact an operator’s experience.

In-cab displays and controls that are intelligently positioned and programmed can go a long way to making the operator’s job easier and more comfortable. Parker’s advanced touchscreen displays

improve long-term operating performance for construction equipment and reduce lifecycle costs using proven technology. Designed specifically for mobile equipment, these PHD displays are compact and lightweight with color touch screens, built-in IO and CAN Bus interface. They are easy to program and test with software simulation as well.¹⁶

Addressing the size of the necessary components housed within the operator’s cab is another important approach. Miniaturizing components and combining functions whenever possible can help address the lack of space available for the operator in the cab. Miniaturization is a key area of innovation in hydraulic fluid conveyance not only for operator comfort, but also for weight reduction and machine efficiency. Working with compact hoses made of rubber or thermal plastic is beneficial. Hose manufacturers like Parker are also able to supply formed thermal plastic hoses that can be customized to fit into tight spaces and kept away from hot or sharp elements, reducing the wear on them. Benefits of using formed hoses include repeatability, reduced misalignment, fewer leak points and less flow stoppage.¹⁷

Steer by wire, mentioned previously, and ride control solutions are outside-the-cab design strategies that enhance operator comfort. Ride control solutions improve stability and reduce jumping, dropping and drifting for wheel loader operators.



Accumulators can be incorporated in wheel loader design as a ride control solution. Used for energy storage, leakage compensation, shock absorption and noise reduction in construction equipment, accumulators absorb shock and reduce noise, all of which less risk for injury or fatigue to the operator as well as increase ease of use. Parker’s piston accumulators reduce field failures that result in downtime and can be customized by size and pressure to be an exact fit for wheel loader applications.¹⁸

Additionally, working with a supplier like Parker who can combine components into a single system reduces both the complexity of a design, as well as the number of components to be included. This comes into play not only for operator comfort, but also for electrification and overall integrating systems to improve wheel loader performance.

Noise Reduction Solutions

Whether it's driven by operator comfort, local ordinances or both, noise reduction is important to construction equipment owners and can be achieved through component design. Suppliers are working to provide OEMs with effective noise reduction solutions¹⁹ ranging from pumps that are optimized to reduce vibrations, friction and pressure pulsations to the inclusion of attenuators or even hoses that can absorb sound.

Noise in hydraulic systems is generated primarily by the mechanical workings of the pump and fluid pulsations exiting the pump as it supplies the flow for the system. It can also be created by any element that causes

turbulence or fluid velocity change. Noise is additive, so small amounts of noise from many components can be effectively amplified, resulting in a significant noise problem.

Noise can be eliminated by adding attenuators that are tuned to cancel out the frequency of the system. Attenuators are effective but relatively expensive and bulky units. There are other methods of noise elimination that have been proven to be effective but are also less intrusive and inexpensive. Wire braided hose can replace steel tubing and relieve some amount of noise due to the full bore inside diameter and the additional volumetric expansion, while the steel wire reinforcement still

provides a good conduit of energy transfer in the form of vibrations through the system. A quick and easy solution to eliminate noise is to install a thermoplastic fiber reinforced hose. These hoses are constructed using a variety of smooth bore polymer inner cores for a high degree of chemical compatibility, high strength fibers and polymer jacket.²⁰

By reducing the amount of noise produced by operating wheel loaders, fleet managers can increase the amount of time that construction crews can work, helping them keep to tight timelines.



Conclusion

Innovation in multiple areas of wheel loader design will continue to drive improvements in all sizes of wheel loaders used in construction. Integrated systems, connected technology and new approaches in all areas from hydraulic systems to steering will make a great impact on this market. Design engineers and OEMs should work with their integrated suppliers to incorporate and standardize these advanced features in order to offer the best value and performance for wheel loaders.

References

1. <https://www2.deloitte.com/us/en/pages/energy-and-resources/articles/engineering-and-construction-industry-trends.html>
2. <https://www.iso.org/standard/43464.html>
3. <https://www.constructconnect.com/blog/electric-dreams-will-heavy-construction-equipment-go-electric>
4. <http://solutions.parker.com/iot-systems-value>
5. <https://www.parker.com/portal/site/PARKER/menuitem.17c8315d31f057bc86a6c3544256d1ca/?vgnextoid=b64bcaa570636610VgnVCM100000e6651dacRCD>
6. <https://ph.parker.com/us/17616/en/universal-tilt-sensors>
7. <https://ph.parker.com/us/17616/en/ferrous-proximity-sensor>
8. <https://ph.parker.com/us/17616/en/accelerometer-and-inclinometer-sensors>
9. <https://ph.parker.com/us/17616/en/rotary-position-sensor>
10. <https://ph.parker.com/us/17616/en/scp-compact-pressure-sensors/2820016>
11. <http://blog.parker.com/engine-power-management-in-construction-equipment>
12. <https://ph.parker.com/us/en/190ls-mobile-directional-control-valve/190ls-mobile-valve>
13. <https://promo.parker.com/promotionsite/globalcore/us/en/new-home>
14. <https://www.lord.com/products-and-solutions/steer-by-wire-tactile-feedback-device>
15. <https://www.proconstructionguide.com/getting-a-grip-on-ergonomics-for-construction-workers/>
16. https://www.parker.com/Literature/Electronic%20Controls%20Division/Literature%20files/PHD_displays_bulletin_HY33-5021-M1.pdf
17. <http://blog.parker.com/how-mobile-equipment-manufacturers-benefit-from-using-formed-thermoplastic-hoses>
18. <https://ph.parker.com/us/21051/en/piston-accumulators-acd>
19. Interview with Parker subject matter experts
20. <https://www.parker.com/Literature/Parflex/B-Parflex%20PDF%20and%20Images/Whitepaper-noise-pro.pdf>

