Engineering solutions for next generation on-road load handling equipment

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Introduction

The on-road load handling industry faces several industry pressures that demand higher performance from equipment with lower carbon emissions. Rapid urbanization and population growth mean that machines must be more efficient and work in more congested areas. Their impact on the public by way of noise or air pollutants should be minimal.

As a result, the industry is rapidly moving towards electrification. Electric equivalents are replacing internal combustion engines (ICE). However, load handling machines are complex, with many integrated components. At the same time, electrical systems are limited by the finite capacity of batteries. Electrification solutions must analyze the machine's performance as a whole and optimize the entire system to meet the needs of the industry within the battery capacity constraints.

The industry is also demanding higher levels of digitalization as end users seek to use the information from sensors to optimize maintenance and monitor equipment health. For example, valves with built in pressure and spool position sensors combined with efficient load control valves offers the foundation needed for future software optimized systems.

Due to the challenges of the industry and the complexity of on-road load handling equipment, OEMs need suppliers who are more like partners in their approach. Partners that understand hydraulic systems, controls, drives, and e-motors can help OEMs optimize their entire system rather than focus on individual items for replacement.

Industry trends affecting on-road load handling equipment

Several global trends are placing demands on the global cargo handling industry. These trends will drive developments in new technology.

Rapid urbanization is creating a high demand for construction activities in congested areas. These activities must have limited impact on the public, cannot generate excessive emissions and must maintain reasonable noise levels. Service providers that use cranes to move containers of recycled material must be efficient and optimized due to the increased number of end-users. For example, the truck loader crane market is forecast to grow from a 2020 base of $1.5 billion by 8% CAGR every year until 2027[1].

At the same time, regulatory pressure continues to increase on emission standards and noise pollution, which impacts the public. For example, European emission limits for carbon monoxide have reduced from 4.5 g/kWh under Euro I (1992) to 0.13 g/kWh under EURO VI (2013)[2].

Almost 200 countries have signed the Paris Accord and affirmed a commitment at COP 26 to global warming to 1.5C[3]. At a local level, this often translates into more stringent emission regulations and penalties like carbon taxes. Global companies are now making their own climate pledges by committing to the UN Global Compact Business Ambition or setting their own carbon neutral goals. These national and corporate initiatives are driving an increase in electrification solutions for the cargo handling industry.

Another area of rapid development, which mirrors the advances in other industries is digitalization. The market for sensors and analytical models is growing due to the benefits of predictive maintenance and equipment optimization. These sensors lay the platform for automating some functions to assist operators.

1 https://www.gminsights.com/industry-analysis/truck-loader-crane-market

2 https://dieselnet.com/standards/eu/hd.php

3 https://ukcop26.org/cop26-keeps-1-5c-alive-and-finalises-paris-agreement/

Electrification solutions for on-road load handling equipment

Challenges:

Moving to electrified systems for on-road load handling offers many environmental benefits, but there are also challenges to overcome. One of the obstacles to adopting electric vehicles is battery capacity and, therefore, the distance a person can drive on a single charge. The same constraint applies to cargo handling equipment. Battery capacity limits the amount of energy available between recharging. Power consumption must be as efficient as possible to make an electrified solution viable in practice.

It is possible to convert from ICE based machines to electrified machines by simply replacing diesel motors with electric drives. However, this approach will not deliver the efficiency that holistically designed electrified solutions offer. It is vital to consider the entire machine and its power management to develop an effective electrification solution. Optimizing the machine during design will ensure a power usage that is reasonable for available energy sources.

Solutions:

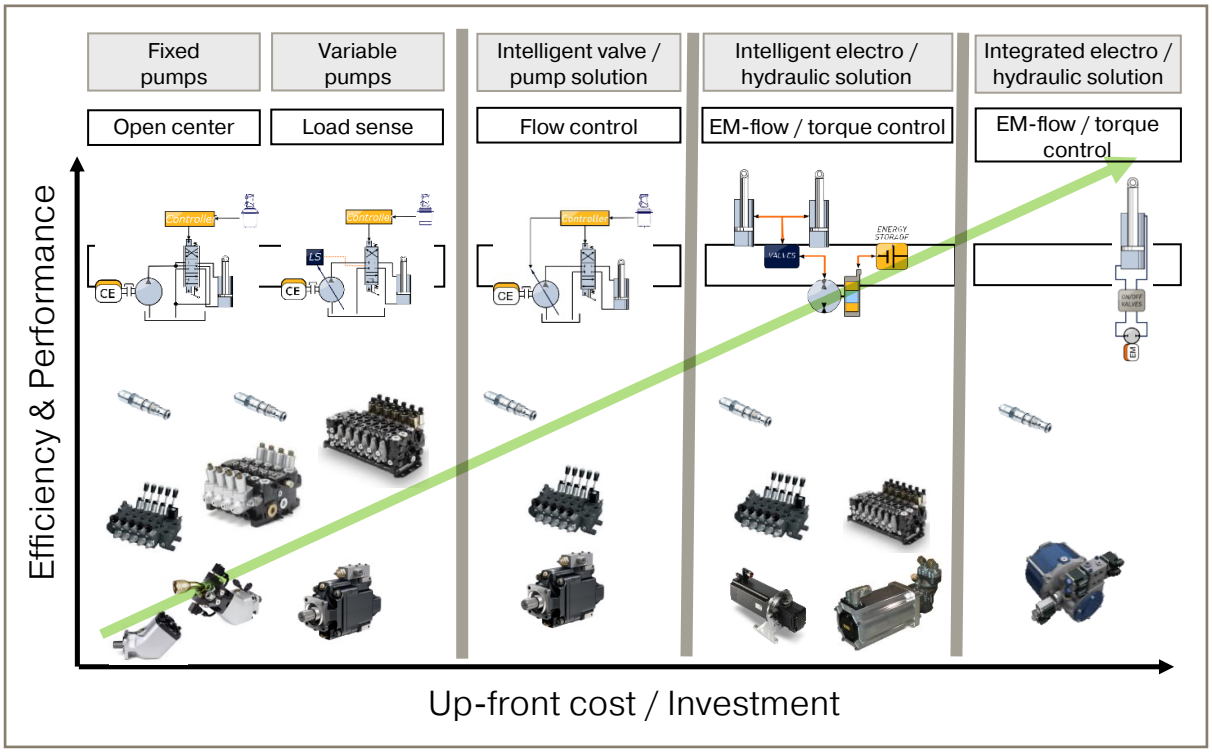
Energy mapping is one key mechanism for understanding the power usage of a machine and how the systems relate to one another. The process involves monitoring its performance in operation and gathering data from sensors. Energy mapping includes an analysis of the heat transfer through cooling systems, the potential and kinetic energy associated with lifting and lowering loading elements, and the power requirements to move the machine. The sum of all the output energy is compared to the input energy supplied to drive the machine. Understanding all this data is essential to design an electrified system that optimizes the machine's work while keeping power usage to a minimum. Some ICE-based equipment (in the mobile market) use only a small percentage of their total energy for useful work. This indicates that there is a significant opportunity for improving efficiency in order to make electrified solutions viable.

Thermal management becomes a significant issue once on-road load handling equipment moves to electrified solutions. Cooling uses substantial amounts of power, which is limited by the constraints of battery capacity. ICE-based equipment could use a single cooling system for the entire machine, but electrified systems need targeted solutions for better efficiency. A single piece of equipment may need separate thermal management systems for hydraulics, eMotors, and inverters. Because many electrified systems use the original ICE-based chassis, there are also challenges regarding available space and distance to the different components. Despite these challenges, electrified thermal management systems deliver excellent performance when designed as an integrated and targeted solution. As an example, high-performance cooling solutions use RPM control to improve efficiency and reduce noise. They can offer 44 kW of cooling capacity in a 0.6 m2 area compared to the 2.4 m2 standard DC cooler.

Product-centered solutions tend to fall short of the efficiencies needed for successful electrification because of their segmented approach. A multi competence with hydraulics, controls, drives, and e-motors delivers a far more holistic solution. A supplier with experience across the entire machine system can offer this multi competence. These suppliers use an integrated approach to optimize the whole machine rather than seeking to get the best out of individual components.

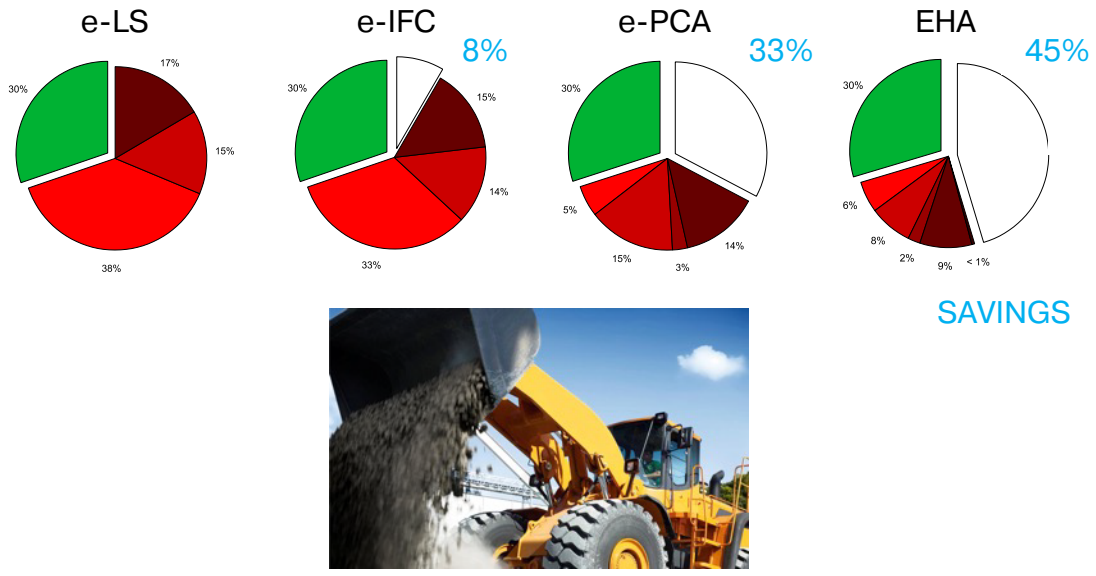
Of course, the more sophisticated the electrification design, the higher the initial investment. For each enhancement, the efficiency and performance of the machine will improve. Still, there is an optimum design that meets efficiency and performance requirements at a reasonable cost. Even if further investment is possible, the additional benefits will not warrant the extra investment. The investment from basic electrification to advanced solutions can be broken down into a series of logical steps as follows:

Energy efficiency system layout



Wheel loader eMobility systems evaluation

Eriksson, B. et al. (2017). Energy Efficiency Comparison of Electric-Hydraulic Hybrid Work Implements Systems. SICF'17. Linköping, Sweden



Evaluation of various hydraulic implement systems with electric prime mover

It is vital to work with a multi competency partner across the entire road load handling equipment for your electrification solutions. This will ensure the achievement of the optimum solution at the most reasonable investment.

Case study:

Consider a cycle refuse truck using a hydraulic pump. Choosing an electric pump with 96% efficiency compared to the 85% standard pump performance delivers substantial benefits in the operating efficiency and the initial investment requirements. For example, a side loader truck may use 18kW for 35 seconds for each pick-up. Assuming 500 pick-ups per day, the total energy demand is 88kWh, of which 10kWh could be saved using the electrified solution. These figures will vary depending on whether charge and recovery systems are built into the solution or whether it operates in a standalone mode with a finite battery capacity.

The cost of a new battery can be estimated at $200/kWh. Therefore, reducing the battery capacity by 10 kWh to 15 kWh equates to saving $2,000 to $3,000 on battery investment alone. The lower energy use also means that the system uses a smaller cooler, contributing to daily energy use savings for operations.

Future developments:

Electrification of on-road load handling equipment is already offering substantial benefits to customers through reduced emissions and better noise control. Still, there are further benefits to be gained and other challenges to overcome as the technology matures. Some examples are as follows:

- **Declutchable truck pumps will save energy by disengaging the pump whenever possible. Studies show that more than 6kW of power losses can be saved for a pump running at 2,000 rpm.**
- **Next-generation valves will offer integrated workport pressure sensors and built-in electronics that enable active damping to save energy.**
- **Kinetic energy recovery can use energy from lowering a load to operate auxiliaries or recharge the battery.**
- **Hydrogen fuel cells or LNG/CNG solutions offer an alternative to batteries where the application has a high-power usage.**

As electrification solutions continue to develop, some of the current limitations will be solved. Battery technology is one area that is likely to improve rapidly due to the global trend towards electric vehicles. This will help reduce the size of batteries and increase their capacity, which will also benefit the cargo handling industry. Future developments will also have to cater for the sustainability of batteries in the form of recycling or repurposing in databanks, for example.

Digitalization for on-road load handling equipment

As end users move to electrified solutions for their on-road load handling machines, controllers and displays are often implemented at the same time. These features enable efficient energy management of the motor and drivers. For this reason, some form of digitalization often accompanies migration to electrified solutions. But there are also other drivers for adopting a broader level of digitalization.

Challenges:

Operators of on-road load handling equipment seek the benefits that digitalization offers other industries. This includes the ability to monitor equipment health so that predictive maintenance strategies can be employed. In addition, information from sensors on a machine can help analyze its performance, allowing higher-level applications or expert engineers to solve problems and optimize the equipment.

Autonomous operations or driver assistance is another crucial benefit of digitalization. Moving an operator out of a hazardous environment eliminates a potential cause of injury. Systems that mitigate against human error, provide a very high speed of response to changing conditions, and handle repetitive tasks can all help reduce safety incidents and prevent injuries. Safety legislators also demand a higher level of diagnostic coverage. Modern machines must contain more sensors and smart devices to verify that all systems are functioning and that the machine's safety features are active.

Solutions:

Sensors are becoming cheaper and more widely available as technology advances. New components like valves have integrated sensors for connection to control and monitoring systems. These sensors provide the information needed for higher-level software applications and safety systems.

Electric controlled pumps or Electro Hydraulic Pump (EHP) systems are an ideal target for sensors and automation. Sensors on cylinders, valves, and pumps can provide information to optimize their performance. Electric joysticks can control the pump flow accurately to minimize losses. At the same time, accurate cylinder speed control can also help to minimize valve losses. This flexibility makes it possible to design the control system for optimum efficiency and lays a platform for future autonomous machine functionality.

Crane tip control is another digitalization requirement for the industry. It uses sensors and control systems to assist operators to simplify crane operation and increase productivity.

The best software automation systems are developed in partnership between suppliers and OEMs. When engineers from both sides work together, they take advantage of both expert technology knowledge and practical user experience.

Future developments:

For digitalization to be fully effective, several elements need to work together. High-quality sensors in the right places provide accurate and valuable information. Software systems perform analytics and troubleshooting to make informed decisions about equipment health or performance. The output of these applications will enable predictive maintenance and autonomous control systems in the future.

Many of these areas are in rapid development by different specialists. However, few suppliers are able to integrate advances in digitalization into the monitoring and control of on-road load handling machines. Suppliers with expertise in the technology and application can help OEMs get the most out of their digitalization initiatives.

A collaborative approach

Engineering solutions for the on-road load handling equipment of the future cannot be delivered by a single entity working in isolation. A collaborative approach is far more conducive to finding solutions to the challenges that the industry faces. Equipment gets used in diverse applications and that each user has unique challenges to overcome. There is no generic solution that can be applied to all. Suppliers with expertise across the entire cargo handling system, including hydraulics, controls, drives, and e-motors have an advantage. When combined with a thorough understanding of the OEM business and operational requirements, the potential exists to make significant advances to equipment efficiency and performance.

A collaborative approach to develop bespoke solutions could take the following form:

- **Work together to determine the customer needs and develop a brief**
- **Analyze machine usage (including energy mapping)**
- **Design a solution using simulation models**
- **Build a prototype**
- **Test and approve the solution**
- **Roll out to the customer organization**

Some suppliers go so far as to establish develop facilities that act as centers of excellence for research and development. It is not uncommon for a customer to deliver a machine to one of these centers with a specific brief of a problem to solve or modification required.

Engineers work with customer experts to evaluate the machine's performance using techniques like energy mapping to determine where the opportunities lie. The center designs, builds and tests prototype solutions for approval and signoff by OEMs.

In ideal circumstances, suppliers get involved at the university level. Companies sponsor research projects aimed at solving their specific challenges or developing new technologies. Supplier involvement at this level of research allows them to add value from the concepts and principles right through to commercial solutions. They bring their industry expertise and long history of product development to projects as early as possible to help facilitate the design process towards practical solutions that meet the industry requirements.

Conclusion

The on-road load handling industry is experiencing rapid change as the industry moves to broader use of electrified systems and more extensive digitalization. These changes are driven by the market demand for sustainable solutions, with many organizations pledging themselves to specific carbon emission reductions.

Electrification is more complex than a simple replacement of an ICE engine with an electric equivalent. Battery capacity limitations mean that existing machines must be optimized to attain the efficiencies required. Energy mapping allows the analysis of machine performance and the development of solutions that minimize power use in the transition to an electric power supply.

Digitized solutions for on-road load handling equipment are also rapidly expanding. A critical development is the introduction of electric controlled valves and pumps combined with needed sensors. This lays a platform for the future development of operator aided functions and efficient systems enabling autonomous vehicles.

Suppliers with experience in road handling operations as well as hydraulic systems, controls, drives, and e-motors are well-positioned to collaborate with customers to solve their challenges and take advantage of the opportunities in their industry.

www.parker.com

European Headquarters
La Tuilière 6, 1163 Etoy,
Switzerland
Tel: +41 21 821 85 00