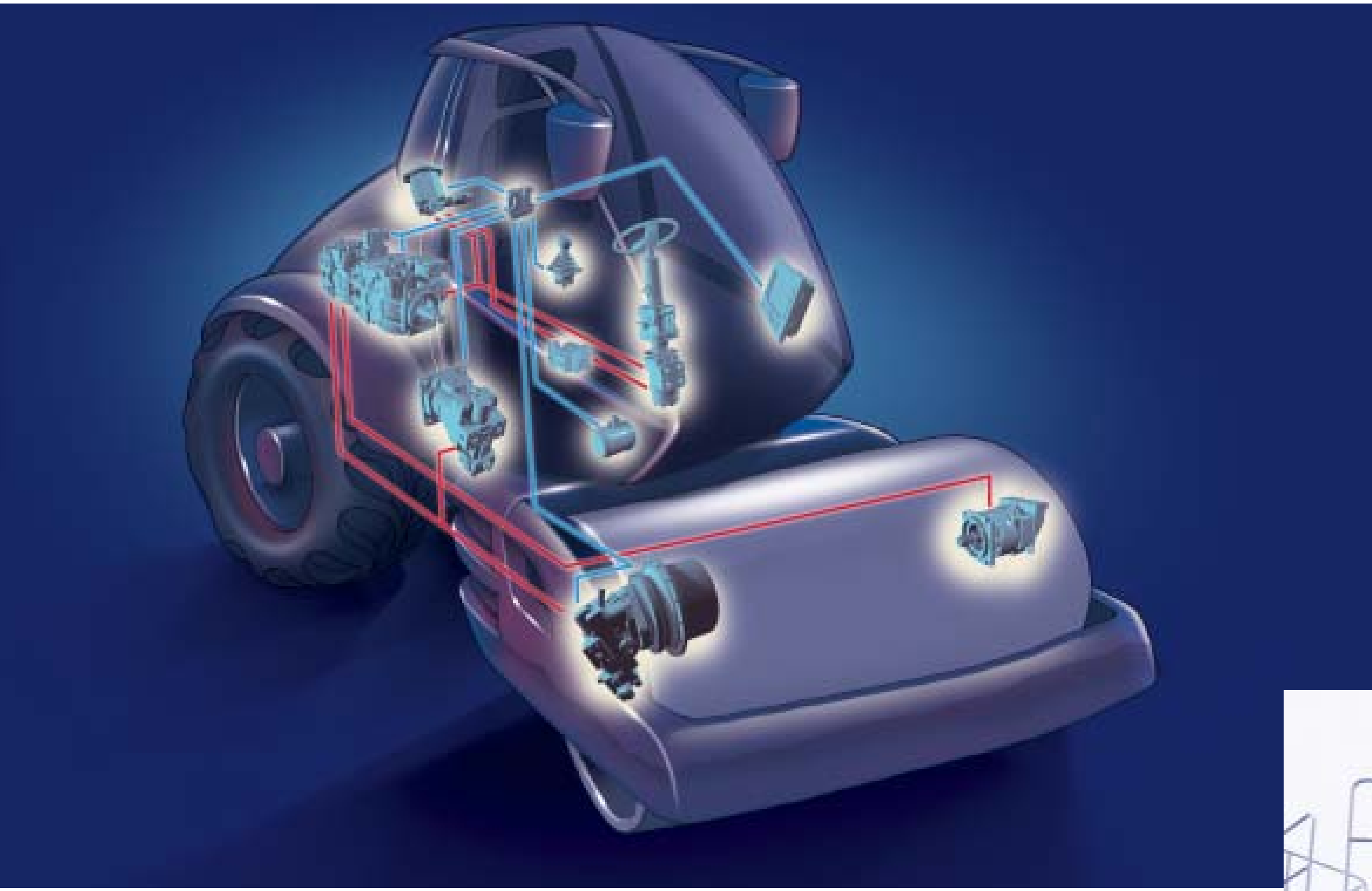
MUSCLE MACHINES



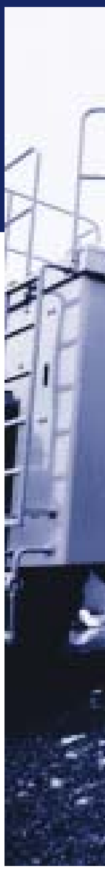
by Steven Gorseth

Since the 1950s, hydraulic systems have been the main muscle of construction equipment. Driven by changes in the market over the years and in response to both government mandates and customer expectations, hydraulic systems have become more efficient, more functional and easier to use. Under the hood of today's site preparation equipment, contractors will find from three to ten microcontrollers with several communication networks between them. But how do these essential power sources work, and how will they be improved in the future?

The Hydraulic System's Concept and Purpose

The concept behind the hydraulic system is to efficiently transfer mechanical power to several locations on the mobile vehicle. The combustion engine, whether diesel or gasoline, is the main power source. A benefit of the hydraulic system is its capability to effectively split power to multiple distribution points rather than to several functional areas through separate engines and transmissions. On today's construction site, very few vehicles with non-hydraulic solutions exist; almost all vehicles have hydraulic power steering and hydrostatic transmission. These systems are flexible with effective transfer efficiencies, normally well above 80%, which is the main reason they are used. Even those vehicles such as graders that normally utilize mechanical or electromechanical transmissions are using hydrostatic front wheel assist.

Further system flexibility and performance enhancements of the hydraulic system are accomplished through the implementation of electronic controllers, sensors and actuators—all together defined as the electrohydraulics system. Today's vehicles equipped with electrohydraulic systems provide more work output with less fuel usage and emissions—something every contractor (and his client) find appealing.



Electrohydraulic System Components

The main components of an electrohydraulic system are its pumps, motors, valves, actuators, cylinders and microcontrollers.

Hydraulic pumps convert rotating mechanical power into hydraulic oil flow. Pumps generate a specified hydraulic flow rate between 1 to 600 gallons per minute (GPM), and at a specific system pressure range between 500 to 15,000 pounds per square inch (PSI). Several pump technologies such as piston, vane or gear pumps are used to meet various market requirements. Due to their small size and high power density (power per pound), piston pumps are preferred for hydrostatic transmission applications. Piston pumps are utilized in higher system pressure applications (> 4000 PSI). Gear pumps are normally utilized on lower pressure and cost-sensitive applications. The majority of vane pumps are utilized in industrial applications such as injection molds, especially when low noise levels are required. Custom configurations such as tandem pumps have also become popular; these setups provide two independent hydraulic sources from one single package. All aspects of expected operational speed, system pressure, operational duty cycle and expected component life goals are important to consider when determining which pump and motor to apply.

A LOOK INTO THE ELECTROHYDRAULICS OF CONSTRUCTION EQUIPMENT.

Motors convert fluid power back into mechanical energy, and have the capability to be controlled in two speeds, either high or low, or with a continuous variable. These motors are normally located near the vehicle wheels, drive gearboxes or any other rotational device like augers or mill grinders. By regulating the flow of power, valves or other actuators allow the vehicle to accomplish the intended work function, whether it is blade control on a dozer or grader; control of a bucket, boom or backhoe; or soil stabilization.

According to some contractors, the biggest benefit of an electrohydraulic system is the orchestration of the complete vehicle operation for best performance. Normally this is accomplished through a controller monitoring various operator input devices such as joysticks, steering panels and brake systems along with sensors that control vehicle speed and operation. For example, most crawlers and graders have load control capability that allow the vehicle to run the engine at the optimum operating point on the torque curve. This maximizes output torque while minimizing fuel consumption and engine emissions. However, if the vehicle runs across an unusually hard surface, such as a temporary dirt road used by loaded trucks, then it will automatically slow down or raise the blade so the engine does not kill.

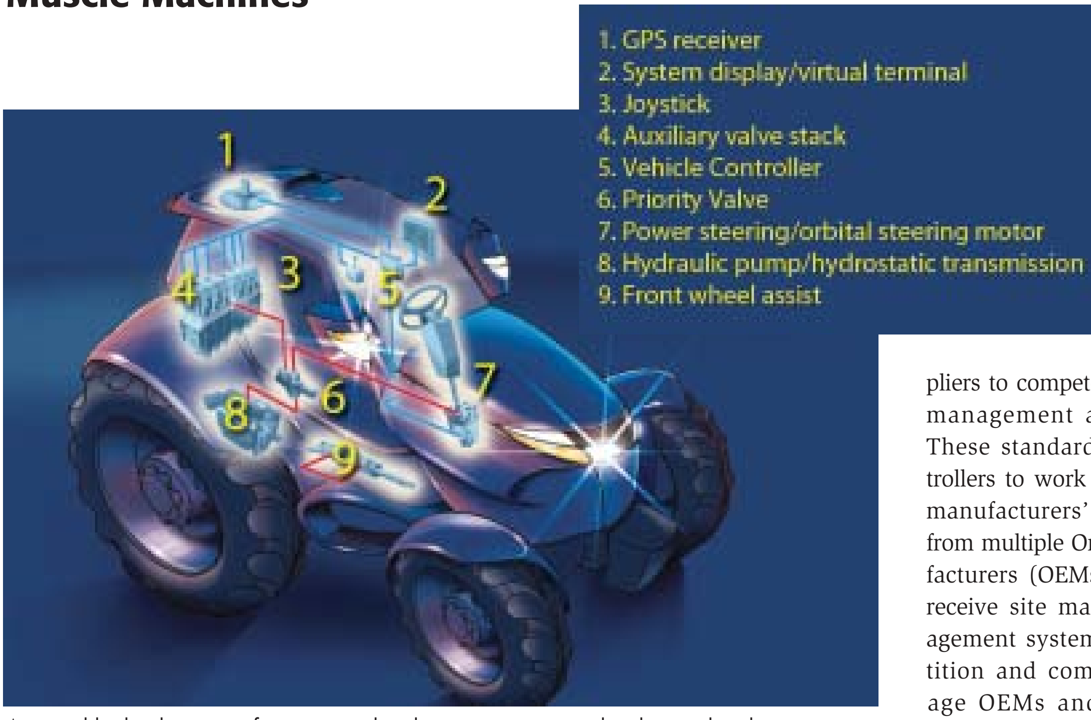
Propelling/Steering Categories

Most construction vehicles utilize electrohydraulics for propelling and steering. The three main propel categories are closed circuit dual path, articulation steering with propel and "Ackerman" four-wheel independent propel/steering.

Crawlers, dozers and skid steer loaders use a closed circuit dual path structure. In dual path applications, there are two separate pumps or a single tandem pump. Each pump provides oil flow to the motor(s) on each side of the vehicle. To use the steering function, the speed is adjusted to the wheels or tracks. The main benefit of this design is the capability to counter-rotate the wheels or inside track, thereby allowing the operator to have a zero-turn radius and maneuver the vehicle in close quarters.

Compactors, rollers and larger agricultural tractors use the propel with articulated steering design. The benefits of this system are slow operation and component cost. Generally, the open circuit gear pump and valves provide a cost-effective alternative to implement smooth steering control.

Some applications require a high degree of maneuverability, such as concrete pavers, aerial lifts or finishing equipment working close to concrete barriers or buildings. As a result, the vehicles must work in several steer/propel modes



A typical hydraulic system for an agricultural tractor using propel with articulated steering.

(crab, articulated, front-wheel and rear-wheel steer modes). To accomplish work in these modes, the vehicle must have the capability to control the speed and direction of each drive wheel or track. This operation is generalized as the Ackerman operation; the speeds and angles are controlled independently.

Microcontrollers and Standards

In the last six years, construction vehicles have undergone a great advancement—that of microcontroller capability with enhanced communication support. Many construction vehicles already have two Controller Area Networks (CAN-buses), normally one J1939 and one proprietary CAN-bus with three to ten controllers. The CAN-bus standard has quickly become the ethernet or communication network of mobile equipment. Many physical implementations exist in accordance with the CAN-bus standard; most require a discrete 120 ohm (electric resistance measurement) resistor to be installed at each physical end of the network. Once this network has been established, compatible devices can be added to the network. The CAN-bus allows sensors to be shared (i.e. only one engine speed sensor reported on the CAN-bus), thus reducing both sensor and harnessing costs. The automotive market has taken distributed networking a step further by applying up to 30-plus controller, sensor and actuator nodes, and up to eight communication networks with a few CAN-buses; some are proprietary single wire interfaces and high speed networks for video and entertainment systems.

The J1939 CAN-bus standard has expanded its specifications to encompass more than engine and transmission communication. Several applications have added specifications to joysticks and positioning messages. Several industries including agriculture, construction and site preparation are utilizing GPS for precise functions. These industries have progressed by defining and ratifying standard GPS and control messages between the task computer and the electrohydraulic control system. They also have defined a standard off-board protocol, allowing various suppliers to compete for the off-vehicle data management and control business. These standard interfaces allow controllers to work across a broad range of manufacturers' offerings and vehicles from multiple Original Equipment Manufacturers (OEMs) to communicate and receive site maps from a single management system. This level of competition and compatibility will encourage OEMs and suppliers to design cost-effective solutions with a minimum level of compatibility for control and site management functions.

The basic guidance structure utilizing GPS focuses on operator override and manual control. These controllers are either in manual mode where they are operated on commands from a joystick or another sensor, or in automatic mode where the vehicle controls command propel, steering and blade work from the task computer. The task computer compares current location and mode, then instructs propel and steering modules to correctly adjust the vehicle control parameters.

Responding to Market Trends

In recent years, the site preparation, construction and agricultural markets have seen significant changes in design processes, often in response to customer expectations. Every vehicle's design must cater to a variety of customers, including operators, site contractors, OEMs, rental companies and government agencies.

Federal and state government have significantly impacted the industry by requiring emission controls on engines; this has forced many OEMs to utilize electronic engine controllers. OEMs seek to recover these additional costs by eliminating sensor duplication and by utilizing CAN-buses to minimize the total system install cost.

The construction and agricultural markets have also experienced a strong push for advanced functionality like load control and machine management. This situation is similar to automobiles with anti-lock brakes. Until a few years ago, anti-lock brakes were a "nice to have" feature. Currently, anti-lock brakes are an expected standard safety feature.

Other industries are exerting forces on the construction market. For example, airplanes are landing and taking off with automatic assistance. Automated Guided Vehicles (AGVs) used in manufacturing plants are minimizing production costs by providing just-in-time or online stocking with no significant operator involvement. Farming practices utilizing GPS have increased efficiency and reduced over-fertilizing the environment. Construction and site preparation applications are realizing efficiency gains by optimizing work performance of individual vehicles as well as fleet management; this minimizes wasted efforts on over-compacting and effectively deploys vehicles and associated personnel resources to ensure the efforts are being successfully completed at the lowest overall cost.

With these trends, it is expected that worksites will become more automated, breaking down the work to optimize costs due to specialized contractors. With the rapid pace of change, OEMs with specific machine management systems may have difficulty integrating all of the data into the systems. Many customers in the construction market hope to see industry standardization so suppliers of site management systems may minimize development instead of adopting several OEM specific implementations. This approach could offer significant advantages for the country's department of transportation, if they accept the design and real-time measurement instead of an additional validation measurement phase. However, both approaches may be required until confidence has been established.

Effects on Design Trends

Due to related market trends, engineering departments abroad are being driven to implement processes that provide more sophisticated features at lower development costs. Three-dimensional vehicle models, for example, have shortened prototype production cycles from months to days.

Today's vehicles have a significantly more robust system through the application of system failure mode effects analysis (SFMEA), process failure mode effects analysis (PFMEA) and highly accelerated life testing (HALT). The purpose of these engineering tools is to detect design failures and conflicts earlier in the design cycle in order to minimize their impact on the full development lifecycle. Customers will fare well to ask questions about the system's operation requirements and validation during the development phase.

What's the Future?

As the market continues to drive OEMs and suppliers to design more sophisticated machines with increased automation, work output in turn has become more efficient. The trend to use electric motor solutions for lower power applications is accelerating, particularly when fuel cells become more economically feasible and technology stabilizes. These enhancements in technology do not necessarily require operators to become highly skilled for some applications. Features such as automatic or remote control operations will significantly benefit contractors in hazardous environmental areas or war zones.

The construction industry may continue to benefit from the establishment of standard interfaces for on-vehicle information and off-vehicle management systems. This standardization effort will be challenging and time-consuming; however, the long-term benefits have the potential to significantly reduce development costs, and potentially allow site managers to effectively deploy and control resources on the jobsite independent of vehicle color or OEM. **SP**

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