Smart Actuators Bring Big Benefits to Utility and Other Off-Highway Vehicles

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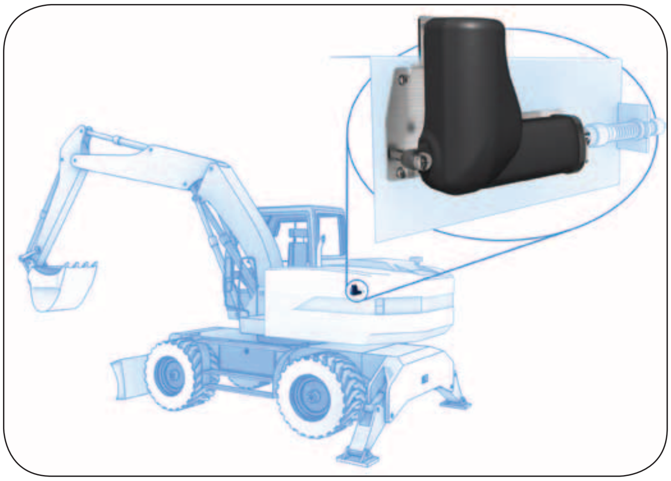

Figure 1 **Throttle actuators allow automatic control of engine speed for reduced noise and emissions, and improved fuel economy.**

Original equipment manufacturers (OEMs) of industrial utility and other off-highway vehicles are adding automated or improved manual control of many features and functions in order to improve performance, safety, ergonomics and cost. Frequently these improvements are based in computing technology that must be translated into physical motion in order to provide a benefit to the customer. Traditional hydraulic and pneumatic controls are often unsuitable for computer-driven operation, so there is a trend towards increasing use of electrical drive solutions. Smart electrical actuators with built-in position feedback, power systems and bus communications provide a cost-efficient solution that converts control logic into smart-motion articulation.

The traditional role of actuators in off-highway vehicles has involved the application of force under the guiding control of the operator to perform a task. As vehicles become more sophisticated, OEMs are adding cutting-edge features that typically involve the use of electronic controls to deliver optimized, more complex and safer motion tasks, etc. For example, a joystick provides inputs to a control that drives electrical actuators that steer the tracks of a skid steer (Fig. 1). Interposing the control system between driver and steering gear makes it possible to improve the safety of the vehicle by setting limits on the speed with which it can be safely driven through a turn. Or, an onboard computer controls a construction excavator to automatically increase the throttle as needed to operate hydraulic equipment and then decreases that throttle to return to the idle position when power is no longer required.

A major obstacle to further advances in this area has been the limitations of conventional actuator technology. Traditional hydraulic and pneumatic actuators typically run from one end of the range of motion to the other without any means for accurate mid-range positioning—required by nearly all of the more sophisticated applications. Pneumatic and hydraulic actuators are sometimes fitted with electronic closed-loop feedback, but this adds considerable cost and complexity since both electronic and hydraulic or pneumatic controls and cabling are needed. Pneumatic and hydraulic actuators also require bulky pumps and valves, as well as the need to send heavy cables anywhere that power is to be deployed or controlled (Fig. 2).

For these reasons there has been a significant trend towards the use of electric actuators. Electric actuators dramatically reduce the number of components needed by eliminating those required of a hydraulic system, such as: reservoir, pump, DC motor, motor relay, solenoid valve, check valve, hydraulic cylinder and pushbutton station. They replace cumbersome and sometimes dangerous hydraulic hoses with small, light wires and use actuators that are usually smaller and lighter than hydraulic cylinders while yet retaining the same force and stroke (Fig. 2). In addition, electric actuators are considerably quieter than a hydraulic system.

One available electrical actuator option consists of servo and stepper motor actuators typically designed to function in an industrial process with a very high level of accuracy and repeatability, and a 100 percent duty cycle. However these motors are quite expensive and, in most cases, their high cost is not justified for off-highway vehicle applications where objects are positioned a few times an hour, rather than continuously, and accuracy of $\frac{1}{16}$ of an inch rather than 0.001 inch is sufficient.

DC actuators provide a much less expensive alternative that still meets the requirements of most off-highway vehicle applications. However, conventional DC actuators require a number of add-on components, such as an

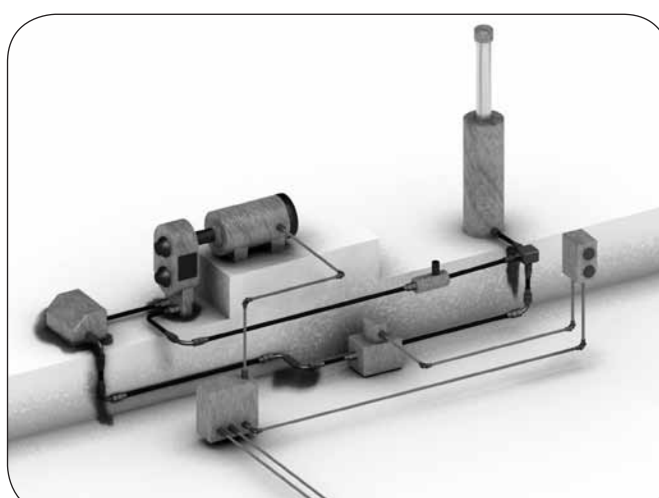

Figure 2 **Replacing hydraulic and pneumatic cylinders with electrical linear actuators enables simpler and smaller installation, easier control, lower energy costs, higher accuracy, less maintenance, less noise and a clean, healthier environment.**

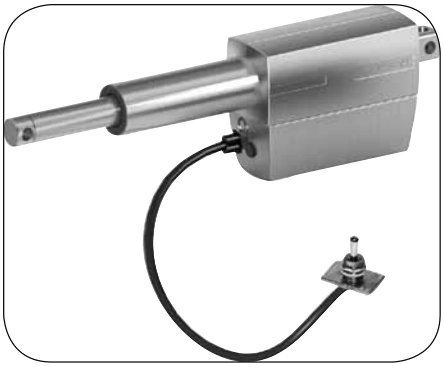

Figure 3 Detail view of a smart actuator developed by Thomson that includes H-bridge, power, control and position feedback systems integrated into one actuator.

H-bridge, which is needed for reversing the direction of the motor, as well as power, control and position sensing systems. These add-ons increase the cost and complexity of the actuator, requiring additional cabling and connectors and extra steps during the assembly process and maintenance.

More recently, smart actuators have been developed specifically to address the requirements of off-highway vehicle manufacturers by packaging the H-bridge, power, control and position feedback systems in a single actuator. Assembly and maintenance of the vehicle are simplified because with the now-integrated H-bridge, all users have to do is connect power cables and bus to the actuator (Fig. 3).

This new generation of smart actuators builds on the proliferation of bus communication that substantially reduces the cost and complexity of integrated vehicle operation. With bus communications, a single control unit can replace the need for multiple single-function controllers. This approach also substantially reduces the wiring required in the vehicle. Bus communication has already been proven in the automobile industry, and is also used in many other vehicle types. Now, manufacturers of off-highway vehicles can utilize the technological advancements and economies of scale that have been developed for the automotive industry in order to increase functionality while reducing the cost of their own vehicles.

With the traditional approach, an electronic control unit (ECU) is required for each actuator. By using a smart actuator with a bus, rather than running a separate cable from the controller to each actuator, as required with the traditional approach, only a single cable needs to run from the controller that passes each actuator. Each actuator control has a unique address, listens to every signal from the vehicle control system, and responds only to signals having its own address.

Actuators also offer the advantage of providing status information. The command goes out to an actuator to travel to a certain position; when the actuator reaches that position it sends a clear signal to the control unit. The actuator can also return position and speed information. The implementation of the bus system also makes it simple to add additional sensors that can track other measurements such as temperature or load.

Smart actuators also provide the opportunity to synchronize vehicle functions. For example, suppose two actuators are required to lift the hood of a vehicle and these actuators must move in tandem with each other in order to ensure that the load is shared between the two actuators. This is difficult—if not impossible—to accomplish with a hydraulic or pneumatic actuator, but can be done easily with smart DC actuators. The control system simply sends out a command to move one step to each of the actuators; it then waits until clear signals are received from each actuator indicating it has reached the desired position before sending the next move command.

Replacing hydraulic steering with electronic steer-by-wire systems offers the potential to add significant functionality by customizing the connection between steering wheel and steering mechanism. Design engineers can easily change the steering ratio with a software command and can even design the vehicle so that the steering ratio can be changed in the field or programmed to change on the fly, depending on vehicle operating conditions. For example, an electronic steering system could be configured to have a high steering ratio at low speeds and a lower ratio at high speeds to help avoid sudden turns at high speed, or configured to allow for rapid maneuvering at low speed. Electronic steering can be programmed to indicate that the vehicle is nearing the end of the steering range by increasing torque resistance. Electronic steering also opens up the door to other more advanced options such as using torque resistance to prevent the operator from steering towards detected obstacles (Fig. 4).

Likewise, smart actuators can be used in agricultural vehicles to optimize the adjustment of harvesting systems in combines. The combine's grain processing chamber takes the threshed grain and cleans it from its chaff by blasting it with air and running it through a sieve. The air flow louver adjustment controls the volume of air flowing through the cleaning system and the louvers must frequently be adjusted to optimize the performance of the cleaning unit for various crop conditions. Too much air flow and you lose grain, too little air flow and the chaff is

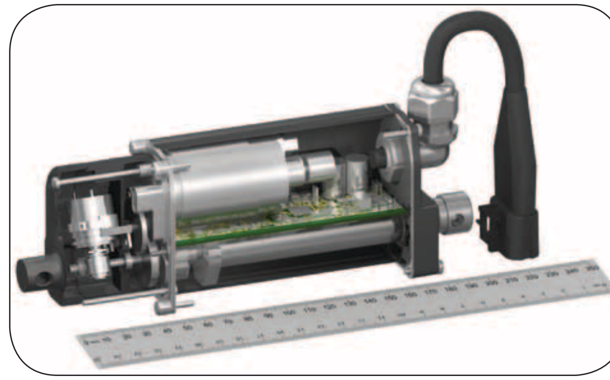

Figure 4 Thomson torque feedback device (TFD) provides variable torque output—in proportion to a DC input—for steering and other by-wire applications.

not cleared. Normally, the operator must climb down from the cab to make these adjustments, which reduces productivity. With electric actuators this can now be controlled directly from inside the cab.

There are many potential applications on nearly every type of off-highway vehicle to combine onboard computers with smart actuators to deliver unique functionality that can set an OEM's product apart from its competitors. OEMs can capitalize on these advantages at the lowest cost by utilizing smart actuators that integrate all of the components needed to deliver motion control in a single package.

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Master Power Transmission

PROVIDES PARALLEL AND RIGHT-ANGLE GEARBOXES

Master Power Transmission (MPT) provides enclosed parallel and right-angle gearboxes for use in many industrial applications including material handling, food processing and mixing. MPT's APG is a gearbox product designed and manufactured in the U.S. for applications requiring efficiency and power density without sacrificing quality and robust performance.

Using Finite Element Analysis (FEA), the housing is designed to be compact while maintaining housing rigidity to ensure shafts, gears and bearings are not exposed to excessive flexure and extraneous loads during operation. Bearing spans for the MPT APG are kept to a minimum to avoid shaft deflection and excessive loads, and all Master APG gearboxes are designed with bearings that will provide a B10 life of at least 5,000 hours.

The spring-loaded lip seals in all APG gearboxes are specially formulated for low drag, reduced heat generation and long life. Each APG unit is factory filled with a long-life synthetic lubricant having a wide temperature operating range well in excess of 200° F at full load, and is USDA H2-approved for most food processing and handling applications.

Gear tooth angles in the helical gearing of the APG are optimized to minimize bearing size, maximize gear load sharing and provide quiet operation. All MPT APG gears and pinions are case carburized and ground for an AGMA Class 9 precision finish. The result is a gear with a very hard outer shell (minimum Rockwell 58Rc) for suitable wear resistance and a ductile inner core that provides the gear or pinion with the toughness required to withstand shocks and vibration.

Many gearboxes use heavy press fits on all mating internal components, making component disassembly and replacement very difficult. Additionally, housings are often cast as one or two pieces, making it very difficult to access internal components. MPT has taken a different approach with APG, keeping disassembly in mind, including pry slots on housing covers. Features such as these make it easy to access the internal components to change seals, bearings and gears whenever necessary.

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