Electric Linear Actuators for Throttle Control in Off-Highway Vehicles
Tips on how to reduce fuel consumption and emissions while increasing productivity

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Electric linear actuators rescue throttle control

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Throttle control design presents engineers with a host of technical challenges. Throttles on drive and auxiliary engines of off-highway vehicles have traditionally been controlled by mechanical cables connected to the driver’s cab. Problems with this approach include the need to place controls in non-ergonomic positions in the cab, difficulty in running cables to engines, and the possibility of inefficient or even unsafe operation due to reliance on the operator to control engine speed.

A new generation of electric linear actuators eliminates the need for cabling by making it possible to control the throttle through an electrical wire or communications bus and optimize the position of the throttle with a control algorithm. The throttle can be placed in a more ergonomic position to improve operator safety. The elimination of the mechanical cable simplifies the design. The control system can operate the throttle to reduce fuel consumption and emissions and increase productivity by ensuring that the throttle is set correctly for whatever function is being performed.

Mechanical throttle challenges

Off-highway vehicles typically have a diesel or sometimes a gasoline engine to drive the vehicle and in many cases also provide a power take-off (PTO) to operate equipment. Often the drive engine is used to power a hydraulic pump that in turn drives a cylinder to perform work such as driving a boom and bucket on an excavator. Many off-road vehicles also have auxiliary engines to operate equipment. Controlling the speed of these engines presents many challenges. Typical examples of off-highway vehicles where speed control can be difficult include skid loaders, excavators, street sweepers and sprayers, asphalt pavers, trenchers and concrete pumps.

Various equipment functions often require that the engine be operated at a specific rpm for a certain function and frequently a number of different speeds are required for different tasks. Operators do their best to hold these rpm levels but with many other tasks to perform the potential always exists for equipment to operate at less than optimal levels or even be damaged due to operator errors. Busy operators often leave the engine running at operating speeds even when the equipment is not being used which increases fuel consumption, noise and emissions. Off-road equipment manufacturers have been making increasing use of electronic controls to improve vehicle operation, however, electronic controls cannot interact with mechanical cables.

The need to run mechanical cables from the cab to the engine or engines creates design and installation challenges. Wire-wound cables have a large bend radius which often limits the areas that they can be run and creates difficulties during installation. Wire-wound throttle cables are often limited to specific areas of the cab and these areas are frequently not the easiest to reach and operate the throttle. Auxiliary engines are particularly difficult to reach with mechanical cables because they are frequently located far from the cab. Periodic lubrication required for wire wound cables is also very difficult to complete and often overlooked causing issues.
Advent of electric linear actuators

Electric linear actuators offer the potential to eliminate many of these difficulties. Linear actuators eliminate the need to run cable from the cab to the motor, substantially reducing design and assembly complexity. Instead, the actuator is installed by the throttle and two wires can easily be run from the cab to the motor. The switch to operate the throttle can be placed in any location in the cab to improve ergonomics and safety as opposed to the limited positions available to wire wound cables. The actuator can be controlled by a simple potentiometer with or without limit switches. The actuator itself can also be positioned for easy installation because no direct access is required for maintenance. The actuator is lubricated for life and requires little to no maintenance.

Interfacing with control system

The actuator may also easily be interfaced with a control system that can deliver substantial improvements in productivity, fuel economy, noise and emissions by automatically optimizing the speed of the motor based on the work that is being performed. Controlling the engine speed with an electronic control system enables the throttle control to be integrated with the vehicle control system. For example, when a particular function is turned on, the actuator can automatically be configured to move the throttle to the correct set point.

The onboard controls can coordinate multiple functions requiring specific power levels and automatically change the speed as needed to optimize performance of each vehicle function. If an operator of a crane is manually controlling the throttle, he or she is likely to keep the engine at the speed required to operate the crane, even when the crane is not being operated for a short period of time. On the other hand, a control system can be configured to drop the engine speed to idle when the joystick is not moved for a defined time interval. When the operator touches the joystick, the control system immediately increases the throttle to a predefined operating engine RPM.

Bus communication advantages

The new generation of electric linear actuators builds on the proliferation of bus communications which substantially reduce 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 amount of wiring required in the vehicle. Bus communication has been proven in the automobile industry and is used in many of today’s off-road vehicles. Manufacturers of these vehicles can utilize the technological advancements and economies of scale been developed for the automotive industry. The bus can provide additional savings by requiring a simple control in the actuator to take commands from the CAN bus.

With a 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, only a single cable needs to be run. Each smart actuator control has a unique address, listens to every signal from the vehicle control system and responds only to signals with its own address.

Electric linear 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 include other measurements such as temperature or load.

Linear actuators also provide the opportunity to integrate the throttle with other vehicle functions. For example, suppose that the engine must be operated at a speed of 2000 rpm to power a hydraulic pump for a specific vehicle function. The control system simply sends out a command to the actuator to increase the speed of the engine. The control system watches the response from the tachometer and turns off the actuator when the engine has reached 2000 rpm. Then the control system turns on the equipment to perform the specific function.

Linear actuators are also designed to withstand underhood temperatures, vibrations and moisture and high cycle life to survive in the tough off-highway environment. Throttle actuators designed for off-highway applications typically meet IP67 or IP69K standards so they can withstand water and particles.

A typical model is designed for 500,000 cycles and can operate on a 50% duty cycle at maximum dynamic load. Models are offered with basic limit switch control and potentiometers with or without limit switches. SAE J1939 is available as an onboard control and custom control capability. Integrating the control into the enclosure actuator housing saves the cost of a separate enclosure for the control.

Actuators are available that can operate from -40°C to 125°C. They are also designed to withstand the shock and vibration seen in the off-highway environment. A typical unit is tested at 100K cycles at 60 pounds at a shock load and 10,000 cycles at 90 pound as well as Random Vibration per MIL-STD-810, Category 24, Level 2 0.014 g²/Hz acceleration, 20 to 2000 Hz frequency, (5.2 G’s) 8 hours in each of three mutually orthogonal planes.

Applications

Manufacturers of off-highway equipment have been quick to use linear actuators for throttle control to improve the performance of their products. One manufacturer of street sweepers uses a custom control to manage electric linear actuators for throttle control. The street sweepers have many different functions, each of which requires a different throttle speed. The custom control and linear actuator ensure that the engine is always operating at the correct speed.

A manufacturer of skid steerers builds one model with Tier 4 diesel engine technology including an electronic throttle to meet emissions standards in developed countries. The company also builds the same model for emerging nations without the Tier 4 technology but faced the challenge of how to operate the throttle in the second engine while offering the benefits of electronic throttle control such as auto Idle, RPM preset points, etc. The OEM discovered that it could use the same engine for both developed and emerging markets by replacing the electronic throttle with an electric linear actuator on the engine for emerging markets. The big advantage is that the company only needs to manufacture and stock a single engine for both markets.
Competitive Advantage

Electric linear actuators offer a wide range of benefits for throttle control in off-highway vehicles. They enable a more efficient and simpler design process by eliminating the need for to run an awkward mechanical cable through the vehicle. Safety can be improved through more ergonomic positioning of the throttle. The design can be made greener by using a control algorithm to regulate the throttle for reduced fuel consumption and emissions. The control algorithm can also improve productivity by ensuring optimal throttle positioning for each vehicle function. The end result is that off-highway equipment vehicle manufacturers can deliver a better product with a competitive advantage.
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