Smart work machines need smart hydraulic propel circuits

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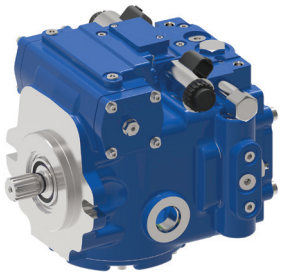
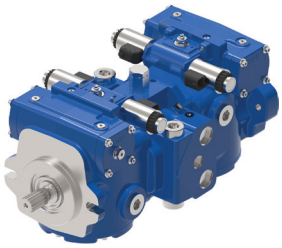
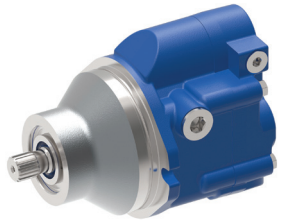






Executive summary

End users of today's work machines expect improvements in performance, productivity, flexibility, and ease of use to deliver better results across several applications. Fortunately, smart control technology has enabled work machines to make improvements in these areas. A new line of Eaton electrohydraulic (EH) control pumps will help smart work machines deliver on increasing market demands for propel applications.

Eaton X70 portfolio

In 2019, Eaton is introducing the X70 pump, a next-generation closed-circuit pump with integration to this smart control technology in Eaton's Pro-FX controls to provide a complete smart propel solution. With initial offerings in 41cc and 49cc max displacements, the X70 provides smart machines measured improvements in performance, productivity, flexibility, and ease of use over today's propel offerings.

Pictured top left: X70 single pump

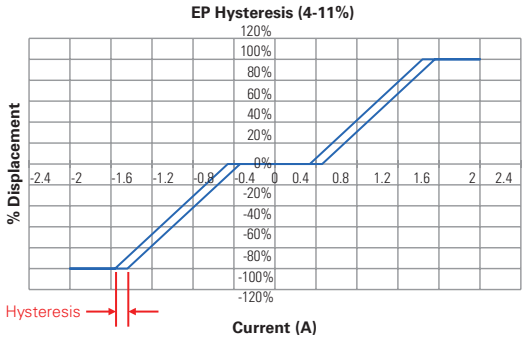
Middle left: X70 back-to-back pump

Bottom left: X70 plug-in motor

Improved performance

The repeatability and flexibility of a hydraulic pump control is an essential requirement for the propel circuit of smart mobile machines. This requirement will have direct impact on the machine's performance. Increased repeatability of the pump from input control position to output flow means a more predictable performance of the machine's movements. The lack of repeatability in hydraulic pumps is variance and measured as hysteresis. Specifically, hysteresis is the variance of input current needed to reach a common pump displacement position through changing operating conditions. The cause of hysteresis in a hydraulic pump is the control system lag or error from the electronic solenoid through the hydraulic control and servo valves.

Most pumps in service today vary in hysteresis between 5 and 10% of the input current at a given flow. In reducing hysteresis, a pump provides more consistent oil flow to the motor; therefore, more consistent speed of the machine is achieved. Eaton's X70 pump has been tested to a best-in-class hysteresis level with an innovative EH control. The non-feedback option of this control has less than 5% hysteresis, and the electronic feedback version dynamically adjusts with the use of Pro-FX and will reduce hysteresis to 1%.



Piston pump hysteresis plot (input current vs. % displacement)

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This performance achievement with both non-feedback and feedback offerings of the X70 pump represents a best-in-class performance level of hydraulic pumps available today, and it comes with standard X70 EH controls. The benefit of this level of pump accuracy is precise and repeatable movement of the work machine, smooth and crisp starts from a stopped position, and improved low-speed motion. Through an improved level of hydraulic pump control, smart mobile equipment propel systems become much more predictable to given input commands, which means better performance at the job site.

Improved productivity

As performance of hydraulic-propelled work machines increases with improved EH pump controls, productivity is improved on these machines as well. Productivity of mobile equipment is increased with operator confidence in the machine behavior. Construction equipment has experienced a recent trend in productivity improvement, as greater precision in electrohydraulic controls have helped optimize machine performance to individual operator and application requirements.[1] If the same control movements of the electronic joystick can produce the same machine response in terms of motion, the operator will not need to be a feedback mechanism to adjust speed of the machine based on applied input to the joystick. Said another way, if a machine's motion has some changing behavior due to control hysteresis, the operator must compensate the input control to gain the desired speed and response from the machine. This caution and adjustment is inefficiency and slows down the machine from completing its required travel.

Skid steer loader working in tight conditions

Application examples can help illustrate improved productivity experienced with more predictable movement of the machine. One example is low-speed control of a work machine in tight conditions. Controlled predictable movement is essential in this application for safe operation as well as for efficiency in moving the machine effectively. Dual path drive systems, such as a compact loader, can also have productivity impacted negatively if variance in a hydraulic control system causes one side of the machine to propel more than the other side. This would move the machine to the left or right when a straightforward path is desired and commanded. If the operator needs to slow down and adjust to keep a straight motion forward, this is inefficiency. For both examples, improved pump control accuracy is important for optimum productivity. The Eaton X70 pump provides improved productivity to working machines through the accuracy of its innovative EH control.

Improved flexibility

Smart hydraulic pump controls offer improved flexibility to today's smart machines, which will be a key factor in market growth. For example, the compact track loader has gained significant popularity in the last five years due to an increased versatility over skid steer loaders, backhoes, wheel loaders, and dozers.[2] As more pump control systems change from traditional hydro-mechanical to electrohydraulic, more versatility is offered to mobile equipment that can leverage these controls in a single controller. Custom and expensive hydraulic controls dedicated to one style of operation can be replaced by less expensive and better packaged EH versions that easily shift from one mode of operation to another.

A machine can switch from automotive drive control behavior to a power mode for heavy digging at low speed. Pressure override can be electrified and added without a special hydraulic valve. Low-speed inching offers more sensitive control and can be readily accessed as required.

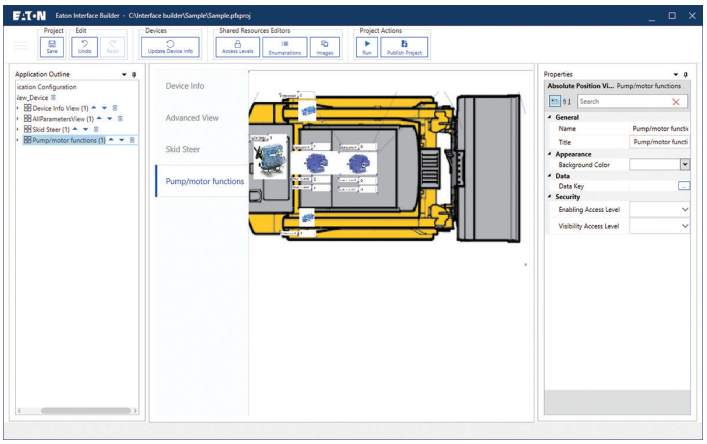
All these functions are part of a growing library of capability that enables more versatility in mobile equipment. Is essence, these smart hydraulic controls and the readily accessed function blocks are putting the "smart" in smart machine propel. Eaton is building function blocks for propel applications that have been tested and field proven. This offering includes Automotive Drive Control, Low Speed Inching, Electronic Pressure Over Ride (ePOR), Engine Anti-Stall Control, Smooth Hot Shifting, and Uninterrupted Shifting. All of these function blocks can be integrated with the new X70 pump EH control in either a back-to-back or single pump configuration.

With Eaton's X70 pump introduction and its integration with Eaton Pro-FX controls, smart machines now have their best option yet for a flexible, high-performing drive solution that is affordable and packaged right for any mobile platform in its power range.

Ease of use

Electrohydraulic control technology is becoming simpler to adopt and manage. Despite the performance, productivity, and flexibility benefits, the challenge with EH control adoption has been the potential complexity that can come with its use. If an EH control solution requires significant programming to customize the software and controller to each application, the benefits might be too far off to pursue. Fortunately, this challenge of complexity has been diminishing greatly in recent years. Adoption of EH controls for hydraulic systems has been growing, as have the availability of function blocks to leverage as needed, which prevents the need for extensive programming. Function blocks are simply graphical subroutines of programming code, which can be dropped into a larger Windows-based developer to create a complete machine system software solution. The use of common function blocks simplifies the total investment of programming needed for a machine application.

Eaton has invested significant effort at growing its function block library in recent years with several successful application startups with new EH control functions. Beyond the machine operating software, the team has leveraged development improvement tools such as auto-tuning feedback controls to improve time to market by reducing the time required to reach an optimal solution for a specific machine and application.



Improved Eaton Pro-FX service tool

An improved service tool for Pro-FX has also been released in the past year, which has simplified machine diagnostics and serviceability. With improvements in adoption of EH technology and improved fleet management with service of smart machines and hydraulic systems, the time to adopt EH control technology is now.

Conclusion

Smart work machines are in increasing demand because of their improved value to a broad range of applications. These improvements have focused on machine performance, productivity, flexibility and ease of use. Eaton's new X70 pump, with its innovative electro-hydraulic control and ready integration with Pro-FX controls, offers a simple path to smart control technology that checks all of tomorrows wants and needs for propel applications.

About the author

Vincent Duray is an experienced global product manager in Eaton's Hydraulics Group with a diverse background in manufacturing, engineering design, engineering testing, and engineering management within industrial technology. His nearly 30 years of experience also include portfolio management, new product development, strategic planning, and capital equipment planning and execution. In addition to achieving Six Sigma Black Belt certification, Vincent has a Bachelor of Science degree in Mechanical Engineering from the University of Michigan and a Master of Business Administration degree from the University of Oklahoma – Price College of Business.

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