Kyntronics
Innovation in Motion

Actuation Know-How

Technical Bulletin for Design Engineers

Kyntronics SMART Hydraulic Actuator (SHA)

Provides Accurate, Robust Closed Loop Force Control Cost-Effectively

Force control or force feedback for linear actuators has been a long-standing requirement throughout industry. Force control allows for repeatable processes and force feedback is vital for data acquisition and process improvements.

METHODS

Open loop via motor Torque Constant

All motors have published torque constants that provide the relationship between the input amperage and the output torque of a motor. Using a simple drive, the output amperage can be monitored and controlled and therefore torque can be controlled. The torque can then be applied to the system to calculate force.

Electro Mechanical Actuator

$$Force = \frac{2\pi \times Torque}{Screw\ Lead} \times Eff$$

Hydraulic Cylinder Actuators

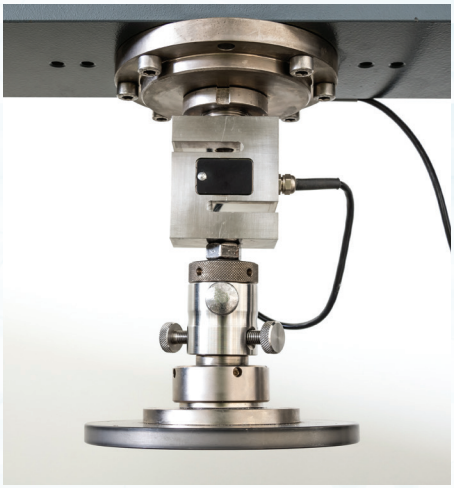
$$Force = Torque \times Pump\ Pressure\ Constant\ (PSI/ft{\cdot}lb) \times Cylinder\ Area \times Eff$$

This method does not yield high accuracy (±10% at best) as the torque constant for each motor deviates from published values and efficiency of the actuator changes over time. For higher accuracy a closed loop system is necessary.

Closed loop via Force Feedback

Closed loop systems require force feedback from an external source. Commonly a load cell is used to determine the force. However, in the case of hydraulics, a pressure transducer can alternatively be used. Regardless of the method, the intention is to use the force feedback to close the control loop (refer to Kyntronics: Motion Control 101 for more details on control loops). This produces much higher accuracy than open control loops using motor torque.

The downside of closed loop force controlled systems is it can be complex and costly to integrate force feedback devices. However, this is not the case with Kyntronics' SHA.



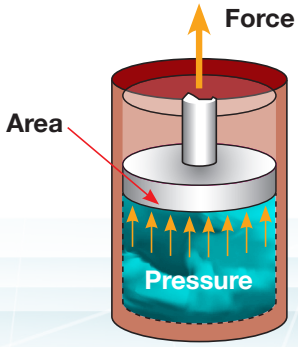
Closed loop force control can add additional complexity to the system

Force Feedback without Control

In some applications, force control is not necessary but force feedback is needed for process documentation. For example, when pressing an assembly into a housing, based on position, the force feedback can be used to verify all the components are in the assembly because a fully assembled unit will generate a corresponding resistive force. Force feedback is also a key feature in test equipment where force is plotted against a position and/or velocity.

HOW IS PRESSURE USED FOR FORCE FEEDBACK IN HYDRAULIC ACTUATORS?

The relationship between Force, Pressure, and Area is well known (F = PxA).



Using this simple rule, hydraulic systems can monitor pressure via a pressure transducer. This pressure can then be applied to the area of the cylinder to accurately calculate force. However, like all instrumentation, pressure transducers have inherent error based on their design and initial settings. First, the internal mechanism of the transducer is set to a specified pressure range. This is known as the full scale. Next depending on the internal tolerances of the transducer, the repeatability is determined. As a result, pressure transducers provide repeatability as a percentage of the full scale output (FSO).

Example:

For a standard 3,000 PSI full scale pressure transducer & 1.5 inch diameter cylinder:

Repeatability = 3000psi x ±1% FSO
Repeatability = ± 30psi

Repeatable Force = Pressure x Area
Repeatable Force = ±30psi x 1.77 in^2
Repeatable Force = ±53.0 lbf

Kyntronics SHA Force Repeatablity

STANDARD FORCE REPEATABILITY AT ±1% FSO (LBF)

Cylinder Diameter	Full Scale	3000 psi	2000 psi	1000 psi
	1	± 23.6	± 15.7	± 7.9
	1.5	± 53.0	± 35.3	± 17.7
	2	± 94.2	± 62.8	± 31.4
	2.5	± 147.3	± 98.2	± 49.1
	3.25	± 248.9	± 165.9	± 83.0
	4	± 377.0	± 251.3	± 125.7
	5	± 589.0	± 392.7	± 196.3
	6	± 848.2	± 565.5	± 282.7

HIGH PRECISION FORCE REPEATABILITY AT ±0.1% FSO (LBF)

Cylinder Diameter	Full Scale	3000 psi	2000 psi	1000 psi
	1	± 2.4	± 1.6	± 0.8
	1.5	± 5.3	± 3.5	± 1.8
	2	± 9.4	± 6.3	± 3.1
	2.5	± 14.7	± 9.8	± 4.9
	3.25	± 24.9	± 16.6	± 8.3
	4	± 37.7	± 25.1	± 12.6
	5	± 58.9	± 39.3	± 19.6
	6	± 84.8	± 28.3	± 28.3

LOAD CELL OR PRESSURE TRANSDUCER

Kyntronics SHA systems use pressure sensors to close the control loop which offer significant advantages. The pressure transducers are fixed to the manifold. This means the transducer and cabling are fixed and removed from the working environment which reduces overall costs and improves reliability for a closed loop force controlled system. Plus, pressure transducers provide equal or better accuracy than alternative force feedback devices. With the SHA, there is no need to sacrifice accuracy for cost.

The SHA is not limited to using pressure transducers. Load cells are an alternative feedback device that can be used to close the force control loop. However, in most cases the load cell is exposed to damage by the working environment and to the working load. In addition, load cell cabling must have special routing to prevent interference with the rod motion. All this adds up to additional costs.

Internal pressure transducers offer robust force feedback and keep sensitive cabling away from machine work (left). While load cells offer similar force control, the exposed connectors, cables, and assembly on the work end offer many challenges (right).

ABOUT KYNTRONICS

Kyntronics motion control and actuation experts have extensive experience in the industrial, aerospace and medical equipment industries. Our in-house team of mechanical, electrical, hydraulic and software engineers have hundreds of years of combined experience solving some of the most challenging application problems.

To discuss your application and see how the SMART Hydraulic Actuator can maximize cost-efficiencies in your business, contact Kyntronics.

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