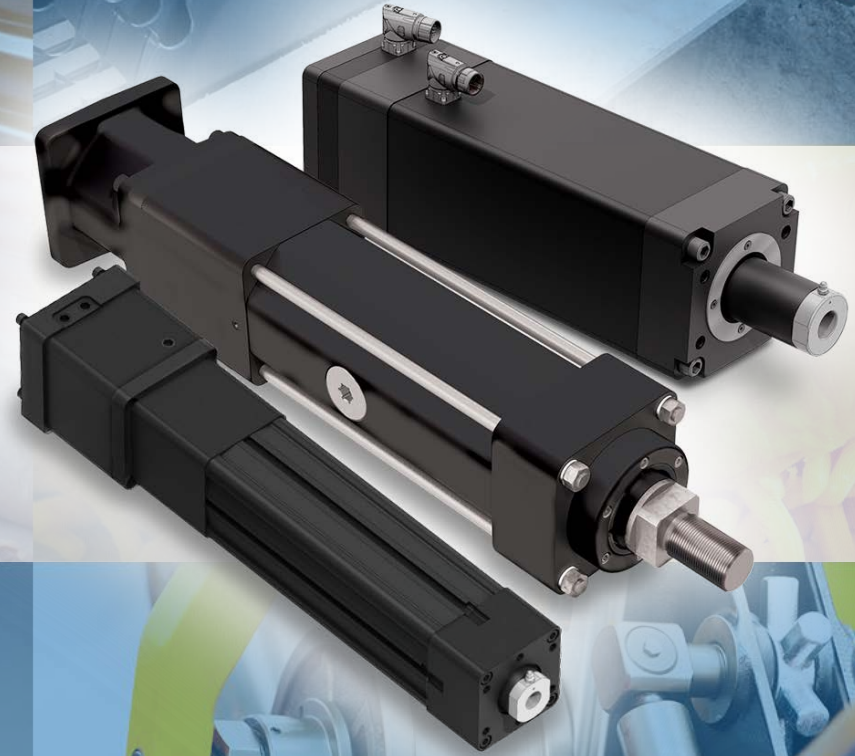
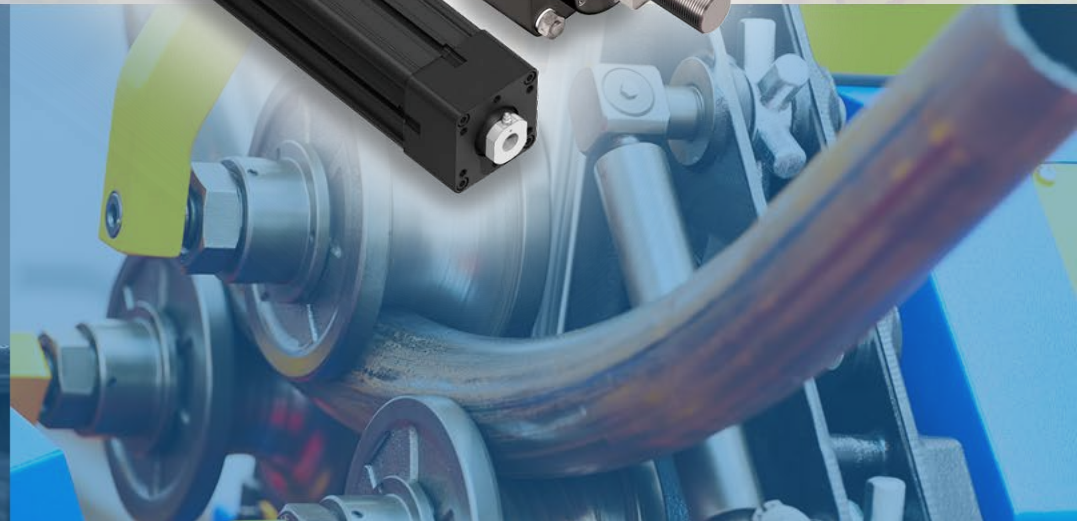
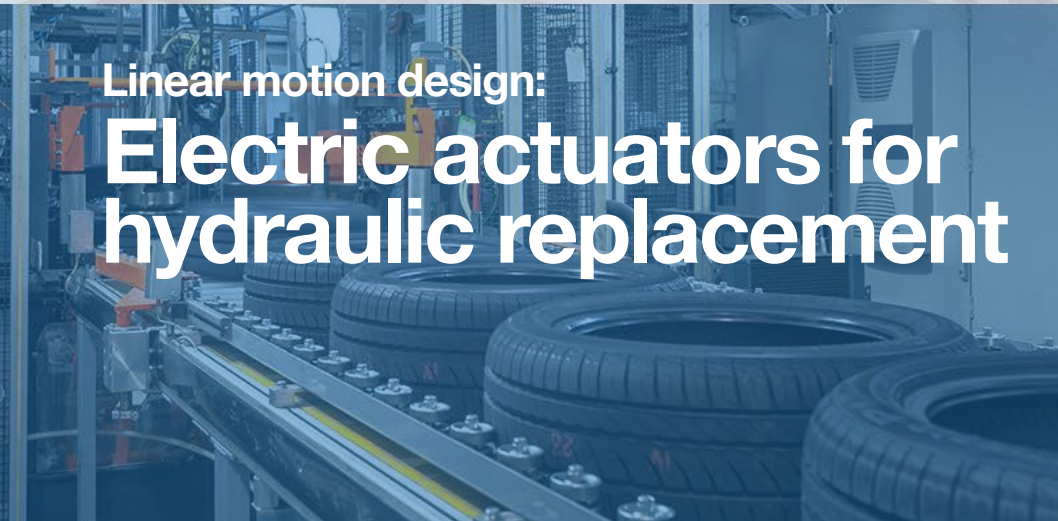



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Linear motion design:
**Electric actuators for
hydraulic replacement**



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Intro

Why electric?

Over the past 30 years, a new type of linear motion technology is, literally, giving hydraulics a run for its money. Electromechanical actuators can provide superior performance over hydraulic cylinders in many applications—through improved precision, flexibility and reliability. Compared to hydraulics, their bore size is equivalent (1 to 5 inches) [25 - 127mm] and exert up to 50,000 lbf [222.4 kN] of force. Electric rod actuators can also reduce the total cost of ownership (TCO) through efficient use of electricity and reduced maintenance.

This eBook compares the two technologies and provides important tips for converting from an existing hydraulic system over to an all-electric solution.



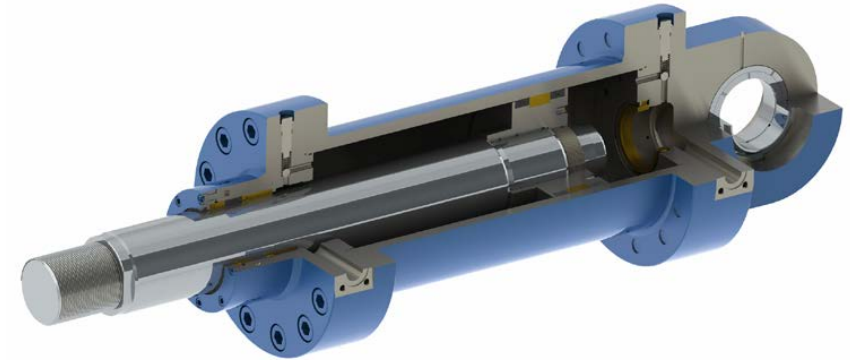
Hydraulics

No longer the only option

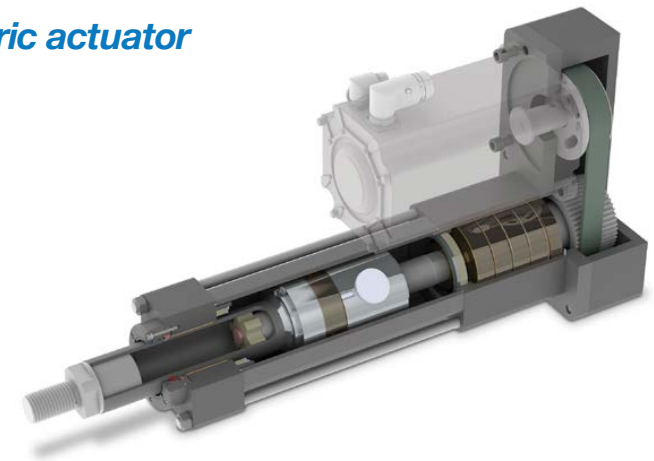
Fluids under pressure produce powerful forces. Hydraulic cylinders can power just about any heavy object that needs to be moved in a straight line, whether fast or slow, up or down: metal presses, conveyor belts, cranes, sawmills and many, many others. Whenever an object is moving in a straight line, it is probably powered by a linear actuator. Industrial-grade hydraulic cylinders include anything from a 1 inch to 8 inch [25 - 203 mm] bore at typically between 2000 to 3000 PSI [138 - 207 bar] range and exert from 1700 to over 110,000 lbf (55 tons) [7.6 kN to over 489 kN] of force.

Hydraulic cylinders have been the workhorse of the industrial manufacturing industry, and they aren't going away. They have an industry reputation for delivering high force, having a compact body, being rugged, simple to deploy and provide a relatively low cost per unit of force. They were the only viable technology for high-force applications for decades. Operators know how to keep their hydraulic machine up and running. However, operators also know the long term issues and challenges.

Hydraulic actuator



Electric actuator



Hydraulics: No longer the only option



It's not a matter of *if* but *when* hydraulic systems will leak or break. Clean-up is messy and time-consuming. When hydraulics fail, the production parts/product may need to be scrapped out and production stopped while repairs and cleanup are undertaken.

Besides the safety issue, hydraulics require a larger overall factory footprint, regular maintenance of their multiple components, and manual changeover, which slows productivity. They are noisy, can be susceptible to temperature fluctuations, don't have accurate multi-position capability and operate in an open-loop environment, which poses challenges for data collection.

These drawbacks are enough for many engineers to look at alternative technologies.



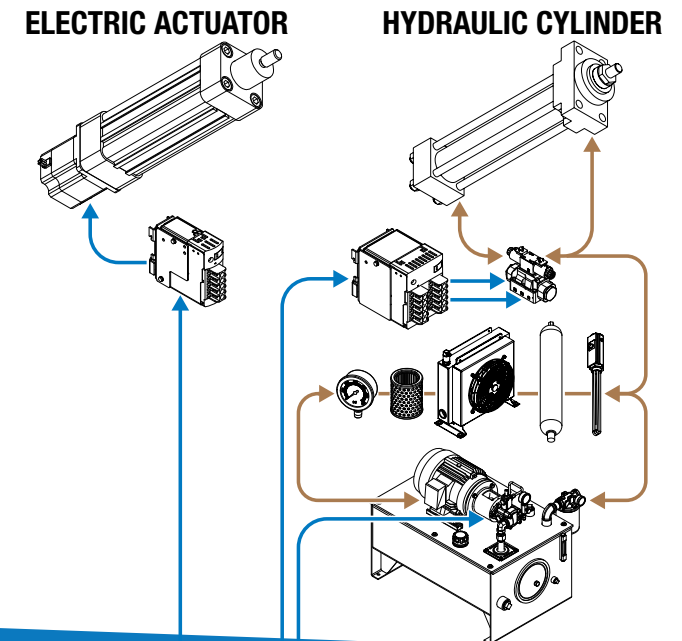
Benefits of

Electric linear motion systems

The main reason engineers select an electric actuator over a hydraulic cylinder is the flexibility of its motion control capabilities: position control (multiple positions, accuracy); velocity control; control of acceleration/deceleration; accurate control of output force; and complex control of all these motion variables in real time. Electric actuators, coupled with a servo drive and motor system, have infinite control over position; accuracy and repeatability levels are far beyond the capabilities of a hydraulic system.

Benefits of electric linear motion systems

- **Thrust capability** – Achieving the extreme forces that hydraulics can produce is entirely possible with electric technology. Actuator and servo component manufacturers provide easy-to-use motion control sizing software, making it easy to specify a system.
- **Force control** – Servo systems using electromechanical actuators constantly monitor torque. This torque correlates to actuator force. It is not uncommon to see force consistency held to within single digit percentage points without the need for any maintenance or system adjustments.
- **Position control** – With closed loop control, multiple positions are easily achievable without the need for external sensors. Settle time for these positions is quick and highly repeatable.



Hydraulic cylinders and required components are more complex than electric actuators

Benefits of electric linear motion systems

- **Temperature** — Electric actuators are generally unaffected by fluctuations in temperature. Unlike hydraulics which may require the oil to be heated and cooled to maintain a consistent viscosity and performance. These factors all vary based on the environment and application.
- **Life and maintenance** — Electric actuators sized for the life of an application require little to no maintenance. Sometimes periodic additions of grease is necessary but there are no filters or fluids that require changing.
- **Data collection** — Hydraulic cylinders require expensive, complex servo-hydraulic systems and/or additional sensors to track and monitor position, velocity, force and other factors happening at the work point. These factors are all built into an electric actuator's servo system.
- **Efficiency/utility costs** — Electric actuator systems typically operate in the 75-80% efficiency range; hydraulic actuator systems typically operate in the 40-55% efficiency range. Efficiency will impact power consumption and ultimately utility costs.
- **Environmental concerns** — Since electric actuators do not contain fluids they do not pose a contamination hazard unlike hydraulic systems. This requirement is becoming more and more common for automation processes.



For a complete discussion of the two technologies, read our white paper:
Electric rod actuators vs. hydraulic cylinders: A comparison of the pros and cons of each technology.

Total cost of ownership

The iceberg principle

Engineers who have been using hydraulics for a long time may not recognize the total cost of maintenance, scrap and lost productivity. Think about it from the iceberg principle: the cost of a hydraulic cylinder is lower than an electric actuator. The hidden costs are under the surface: Installation, operating costs, disposal fees, environmental costs all add up to the Total Cost of Ownership of a system.

Electric servo systems can cost more to install than hydraulic systems. But that's not the bottom line. Electric systems operate more accurately, flexibly, efficiently and with little or no maintenance over the life of the system. As a result, their total cost of ownership is lower over the life of the equipment — making them an attractive alternative to hydraulics.



Total cost of ownership: The iceberg principle

“many leaks identified in hydraulic systems are left to drip away the profits of a company - **profits lost with unnecessary energy consumption, reduced equipment performance, decreased reliability,** increased fluid costs, increased housekeeping costs, etc.”

Machinery Lubrication article – Detecting and Managing Hydraulic Systems Leakage

Why electric actuation systems can have a lower total cost of ownership compared to hydraulics:

Improved process control

- Complete motion control flexibility
- Accurate and repeatable motion control
- Provide process optimization

Improved reliability

- Simplified electric actuator system
- Minimal to no maintenance
- Predictable, long, consistent life

Improved efficiency

- High efficiency servo actuator system
- Power on demand

Improved risk mitigation

- Clean electric actuator technology (no leaks)
- Safe working environment

Sizing and Converting Tips

Converting a hydraulic cylinder to an electric actuator system requires understanding three key variables: **force**, **motion profile** and **electric actuator technology**.

The first step in the conversion process is to understand the amount of work being done. This work (force) is a function of the hydraulic pressure in the cylinder. However, getting an accurate measurement of the force being applied by hydraulics can be tricky. The most common conclusion is to use the maximum-rated pressure of the hydraulic system. This assumes that prior engineering work didn't significantly oversize the hydraulic system. Over-sizing a hydraulic cylinder is common due to the relatively small effects it can have on the overall cost of the system. This is not the same with electric actuators. Their costs can be affected significantly when too much safety margin is built into the design. ***The biggest mistake is to oversimplify the force calculation process.***

Converting a hydraulic cylinder to an electric actuator is not as simple as calculating system capabilities. Oftentimes this is done by using the basic formula shown below. We refer to this as the System Pressure Method, since we are applying the maximum rated pressure of the system to the full piston area of the cylinder.



Sizing and Converting Tips

Calculating using the system pressure method results in an over-sized, over-priced electric actuator solution.

System Pressure Method: Not recommended

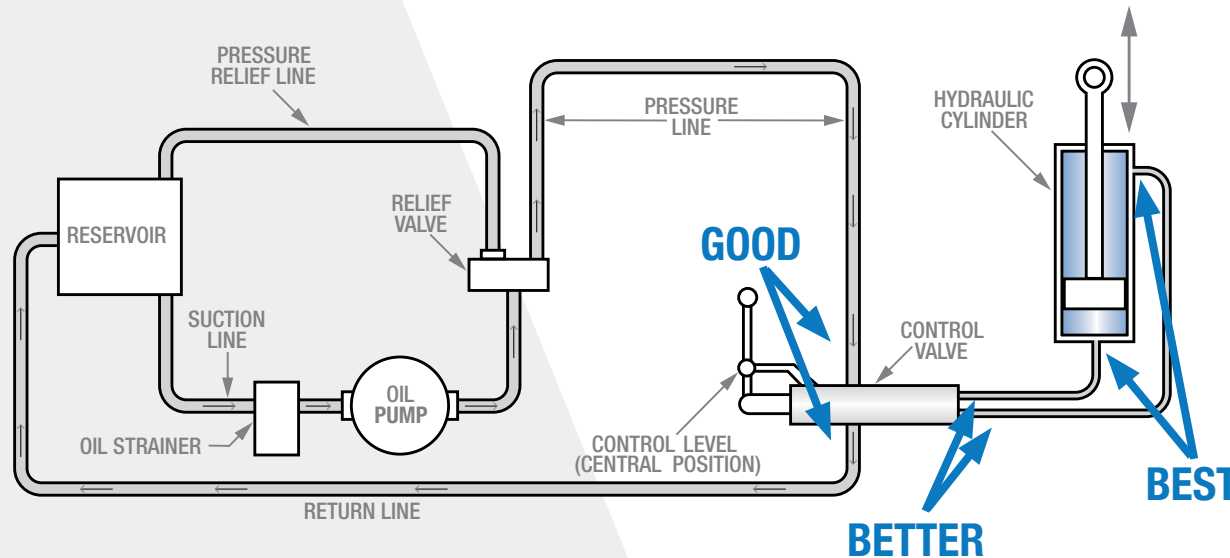
Force = Area of the cylinder x rated system Pressure

The full dynamics of a hydraulic system may not always be fully defined or known. Because of this, engineers often apply conservative values to ensure proper operation and build in a factor of safety. This approach will almost always result in an over-sized, overpriced electric actuator solution.

To prevent over-sizing the actuator, determine the true peak and continuous working force of the hydraulic cylinder. The best approach to accomplishing this is to record values of the application while in operation. This can be challenging, especially on an existing machine. It may be difficult to get an exact pressure reading, but even a pressure estimation within 15 percent of the actual force will provide a reasonable range.

Sizing and Converting Tips

The best way is to determine these application forces would be through the use of a load cell or the use of an electric actuator installed in the application. But this can be difficult or impossible to implement in existing machines or equipment.



The next best and most practical way is to measure hydraulic pressures in the cylinder while the process is in operation.

In general, there are three different areas on a hydraulic system to take pressure measurements.

The closer you can get to the point of work, the more accurate your measurement.

GOOD

Measure pressure at the valve. This is the most common for conversion applications. It is the furthest distance from the work point, which can increase error in actual vs. measured pressure.

BETTER

Measure pressure between valve and cylinder. Pressure-compensated flow controls and needle valves or other inline accessories may have an influence on pressure.

BEST

Measure pressure at the cylinder. The most accurate location for reading pressure is closest to the point of work. This area may be the least accessible.

Sizing and Converting Tips

Conservative measurements get you close. Accurate measurements get you where you need to be so that actuators and motors aren't undersized or significantly oversized.

Take a video of the process in motion to learn how much time is needed to make the desired travel distance. This is useful for sizing up the mechanical assembly and support finalizing motor and drive selection.

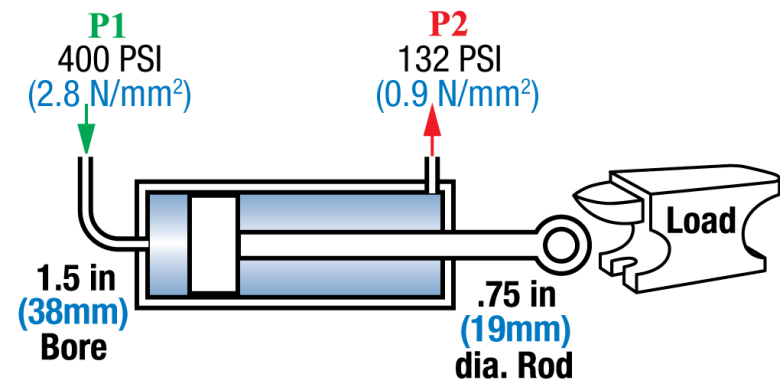
Also take a video of any pressure gauges used in recording pressures. This will enable a review of pressure across the entire stroke to better identify if there are pressure spikes that should be accounted for.

Make a note of process requirements that must be maintained such as a constant velocity or a time to complete a move. An application sizing worksheet can be a useful tool to document these requirements and provide a quick snapshot of what is necessary for a specific application.

Most Accurate Method

- ☑ Force on each side of the cylinder is calculated
- ☑ Area of Rod side of Piston = bore area - rod area
- ☑ Application force = difference in force for each side

$$\text{Force} = (\text{Area}_1 (\pi r^2) \times P1) - (\text{Area}_1 (\pi r^2) \times P2)$$



Sizing and Converting Tips

We recommend that you measure not only the working pressure in your system but also the return pressure. Every hydraulic system is different. Usually there will be minimal backpressure in return lines, but some systems can have high return pressure between the cylinder and the valve. In these instances, this pressure does have an impact on what the output force of the cylinder is (see below).

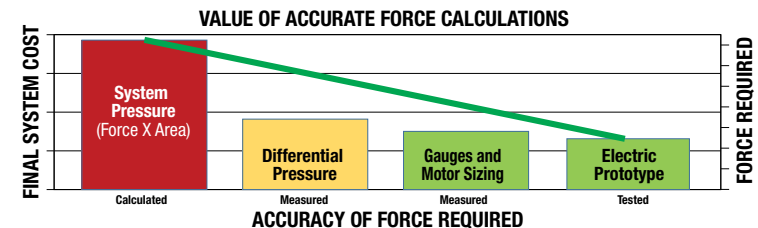
U.S. Customary

$$\begin{aligned} \text{Force} &= (\text{Area1}(\pi r^2) \times P1) - (\text{Area2}(\pi r^2) \times P2) \\ \text{Force} &= [(\pi \times 0.75^2) \times 400] - \{[(\pi \times 0.75^2) - (\pi \times 0.375^2)] \times 132\} \\ \text{Force} &= (1.767 \times 400) - (1.327 \times 132) \\ \text{Force} &= 706.8 - 174.9 \\ \text{Force} &= \mathbf{531.9 \text{ lbf}} \end{aligned}$$

Metric

$$\begin{aligned} \text{Force} &= (\text{Area1}(\pi r^2) \times P1) - (\text{Area2}(\pi r^2) \times P2) \\ \text{Force} &= [(\pi \times 19^2) \times 2.8] - \{[(\pi \times 19^2) - (\pi \times 9.5^2)] \times 0.9\} \\ \text{Force} &= (1140 \times 2.8) - (850 \times 0.9) \\ \text{Force} &= 3144 - 778 \\ \text{Force} &= \mathbf{2366 \text{ N}} \end{aligned}$$

The most accurate force calculations determine the dynamics on both the blind (piston) end and the rod end of the cylinder. There is force whenever pressure is applied to a surface area. Therefore when back pressure is applied to the rod end of a cylinder during an extend move, it will offset some of the force that is being applied by the primary working pressure to the blind end of the cylinder. This must be accounted for. When calculating these forces and the resultant force, we will call this the Dual Force Method. The example to the right compares a relatively high back pressure to the primary working pressure.



Sizing and Converting Tips

We'll assume that the pressure rating of the system is 103 bar and use this as the basis of our force assessments. Using the "Area X Pressure" method and the same cylinder size, you see that while only needing 2366 N of thrust, we would have sized a system five times larger than what was required.

This example uses very small forces compared to what typical hydraulic systems can produce, but it highlights the importance of identifying and using accurate application data. When sizing hydraulic cylinders, it may only cost a few hundred dollars to oversize by selecting a larger bore size for more force. However, oversizing an electric actuator—by using double or triple the required force capacity—can add thousands of dollars of unnecessary cost to the system. That is why proper measurements are key to right-sizing electric actuator systems.

For more information

[Video: Advantages of converting](#)

[Video: Sizing electric actuators for hydraulic replacement](#)

[How-to guide](#)



Application examples

Making the case: Why convert a tube-bending machine from hydraulic to electric

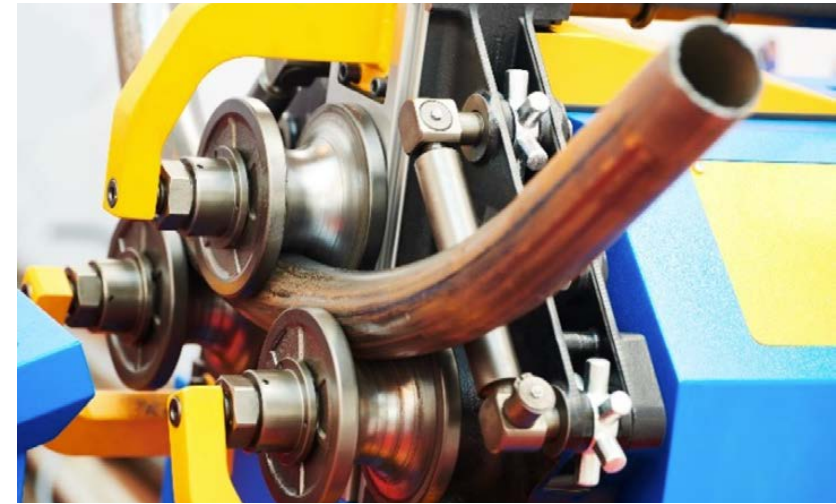
The fundamental reason: To make better parts

Tube-bending machines have been driven by hydraulics for the past 80 years. These machines bend miles of mild steel, stainless steel, copper or aluminum tubing at infinite angles and make a variety of components, from vehicle headrests to air conditioning heat-exchange pipes.

Sure, there's some waste, but this is the way they have always done it. Hydraulic-driven machines have still been the best way that manufacturers know to bend metal tubes.

But what if there's a better way? One that produces better parts?

Previous pages discuss the significant advantages of electric actuators over hydraulic cylinders: zero maintenance, longer life, no hydraulic fluid, efficient, quiet, clean, accurate. And, there are arguments against using electric actuators to bend tubes: electric actuators take up more space next to the working area, they cost more and they are a new technology that requires training time and expense. Operators may need to be “sold” on the idea of learning something new.



Application Examples

The fundamental reason to consider changing to an electro-mechanical system: electric actuators make better parts than hydraulics.

By “better,” we mean less waste and tighter tolerances. And we do that through force feedback, which tells us how hard the actuator is pushing and then coordinating the move with force and position.

This applies whether the machine makes tubes that are used as structural members (such as vehicle roll cages, chassis frames, head rests, ornamental iron work, awning frames, fence gates, furniture and more) or tubes used for fluid transfer (heat exchangers for air-conditioning or industries such as petrochemical, automotive, medical).

How it works for head-rest tubing

Head rests use the lowest quality, least expensive steel tube, called electric-weld tubing. This type of tubing starts flat and is rolled to the required thickness. Wall thickness and seam location tolerances for this type of steel are very loose. A major parts quality issue is the tube’s “spring-back”; after a tube is bent, the piece bounces back a little. The tube thickness and seam location determine how much spring-back occurs. Locating the seam along with compensating for thickness variations are challenging. Auto makers set a tolerance for spring-back, and bent tubes that are not in the tolerance range are thrown away—they can’t be re-bent.



An electric system will allow tighter tolerances—and less waste—because force feedback allows the machine to adjust the actuator stroke for each bend. Testing identifies various combinations of seam location and how much force is required to bend the tube to the correct position for that seam location.

Force feedback, used to compensate for tolerances in wall thickness and the welded seam location, can help a machine designer reduce scrap by 80 percent.

Application Examples

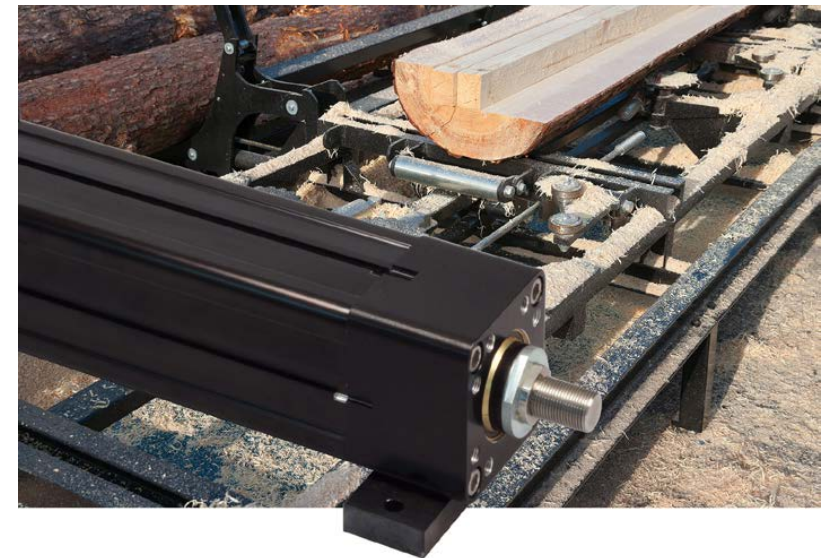
Making the case: Switching from hydraulic to electric linear motion in the timber industry

High-force hydraulics are used throughout the timber industry to create linear motion. Increasingly, lumber processors are looking for ways to reduce or eliminate hydraulics from machinery. Leaking hydraulic fluid, high maintenance costs and low system efficiency are the driving factors.

Positioning the roller on a timber-planing machine

Responding to customer requirements, a manufacturer of lumber processing equipment needed to find a robust, long-lasting alternative to hydraulics used to position the machine's rollers on the planer. Maintenance issues and temperature fluctuations caused inconsistent and sluggish performance. In addition, the solution needed to withstand the shock loads caused when the machine's roller found gaps between the boards as they travelled through the planer.

A modified Tolomatic [RSA64 HT](#) high-force linear actuator, with roller screw and IP67 seals, provided the electric alternative the manufacturer needed. The IP67 rating protected the actuator from splashing water, sawdust and other contaminants.



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Application Examples

In addition to high force, the actuator provides the required stroke length of <152 mm and speed of 152 mm/sec.

Benefits of converting to an electric system

The rod actuator's durable construction and roller screw design ensures long life and consistent performance with minimal maintenance. In addition, due to the high shock loads of the application, a custom steel head with an integrated trunnion improves the actuator's overall ruggedness.

The new electric linear motion system eliminates environmental risks related to contamination by leaked hydraulic fluids. Also, the new system reduces maintenance costs and improves performance reliability in low and high temperatures with decreased susceptibility to premature failures.



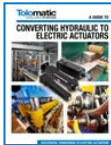
Resources

You don't have to be a hydraulic expert. A wealth of support information is available to you for reference. Our team of application engineers is also available to discuss your application.



Online resources

How to convert hydraulic actuators to electric



Brochure

Guide to converting hydraulic to electric actuators



Whitepaper

Electric rod actuators vs. hydraulic cylinders: A comparison of the pros and cons of each technology



Infographic

Comparing intelligence and operations of electric vs. servohydraulic vs. hydraulic actuators



How to guide

Converting hydraulic cylinders to an electric actuator alternative



Video

Advantages of converting hydraulic to electric linear motion



Video

Sizing electric actuators for hydraulic replacement



Blog

"Back and Forth"



Ask an engineer

Get a question answered or request a virtual design consultation with one of our engineers.

Tools



Online Sizing Software

Size and select Tolomatic electric actuators with our easy-to-use online software



Your Motor Here

Select the motor of your choice. Your actuator ships with the appropriate mounting plates and couplers for quick and easy install



CAD Library

Download 2D or 3D CAD files of Tolomatic products



Application Checklist

Download our form for easy assistance in selecting the best actuator for your application

Products



RSX extreme force electric rod actuators

- Roller screw driven
- Forces up to 50,000 lbf (222 kN)
- Flexible motor mounts



IMA integrated servo motor actuators

- Food-grade white epoxy coating
- Forces up to 6875 lbf (31 kN)
- IP67 rating



RSA HT heavy duty electric rod actuators

- Add any servo motor
- Forces up to 13,000 lbf (58 kN)
- Economic ball screw options



ERD hygienic electric actuators

- IP69k, clean-in-place
- Forces up to 7868 lbf (35 kN)
- USDA and 3A hygienic design approved



ServoWeld resistance spot welding actuators

- Multiple designs for various weld guns
- 20+ million welds
- Superior welds and force repeatability