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White Paper

Actuators for Automotive Pressing Applications

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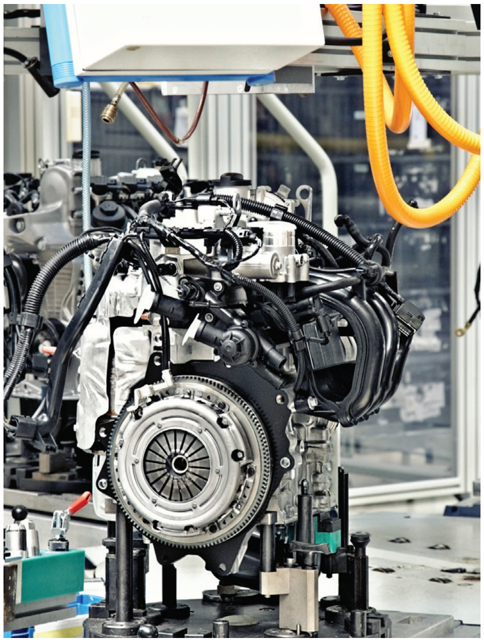
Pressing operations are an integral part of the complex process of manufacturing a vehicle. Automobile and Tier 1 suppliers rely on pressing operations to insert bearings, bushings, gears, gaskets, and more in their assemblies.

Each operation must be done with repeatable accuracy in order to maintain the high quality and safety standards expected from these products. At the same time, productivity constraints dictate that operations are completed as quickly and efficiently as possible with minimal downtime.

Press systems need to strike the unique balance between performance and cost, whether it is pressing bearings on axle shafts or welding vehicle frames. Actuator selection for these machines is critical to the performance of the system, and to the total cost of ownership of the manufacturing facility.



In automotive applications, actuators are used in presses that insert bearings, bushings, gears, and more into vehicle assemblies. Electromechanical actuators are often chosen for these applications due to their efficiency and accuracy.

Engineers are constrained by numerous factors that influence which actuator they should utilize in their machine design. At a high level, these factors include performance, life, package size, and total cost of ownership. Each of these factors are important for any application, but can be the difference between best-in-class throughput and costly downtime in automotive manufacturing.

Common Actuator Types

There are three main classes of actuators: pneumatic, hydraulic, and electromechanical. Each type has its own unique benefits and drawbacks, and applying them correctly is a critical task for every machine builder.

Pneumatic actuators are powered by compressed air. As the pressure changes in the cylinder, the drive piston extends and retracts at forces proportional to the pressure. The major advantages of these simple devices are speed and cylinder cost. However, their accuracy is low, and their speed is difficult to control due to air's high compressibility.

Hydraulic actuator designs are similar to that of pneumatics, except that the working fluid is oil. The use of an incompressible fluid gives hydraulics high force density and the ability to hold a position without additional energy input. These actuators are very durable and have better accuracy than pneumatics. Major downsides to hydraulics are environmental risks due to leaks and their relatively slow speed. These downsides can potentially create unsafe work environments, compromise performance, and reduce efficiency.

Electromechanical actuators operate on a different principle, using electric motors to create torque, which gets translated into linear motion via a roller or ball screw mechanism. This approach results in extremely accurate and efficient actuation. Most electromechanical actuators are either coupled to a servo motor or have a servo motor integrated into the device. This provides for closed loop control, allowing users to program and precisely control the actuator's position, speed, force, and acceleration.

The performance of an electromechanical actuator is in large part determined by its type of screw drive. Ball screws use ball bearings to carry the load between the screw and the nut, and are often selected to replace inefficient and inaccurate pneumatic actuators at similar force densities. The simple ball-screw design competes with pneumatics on total cost, when taking into account collateral equipment like compressors and tubes, maintenance costs, and energy efficiency.

Roller screws use threaded helical rollers in a planetary arrangement, which permits higher force transmission and extended life. Roller screw actuators are more frequently replacing hydraulic actuators in pressing applications. Single-axis actuation with a roller-screw-type electromechanical actuator is similar in overall cost to that of a standalone single axis hydraulic press, but savings in energy and maintenance with the electromechanical actuator can add up over the equipment's lifetime.

Actuator Selection Factors

	Pneumatic Actuator	Hydraulic Actuator	Roller Screw Electric Actuator	Ball Screw Electric Actuator
Load Rating	Low	Very High	Very High	High
Lifetime	Can be Long with Proper Maintenance	Can be Long with Proper Maintenance	Very Long	Moderately Long
Speed	Very High	Moderate	Very High	Moderate
Positioning and Repeatability	Very Difficult	Difficult	Easy	Easy
Relative Space Requirements	High	High	Minimum	Moderate
Actuator Cost	Low	Moderate	High	Moderate
Efficiency	< 50%	< 70%	> 90%	> 90%
Installation and Maintenance	Difficult	Very Difficult	Low	Moderate

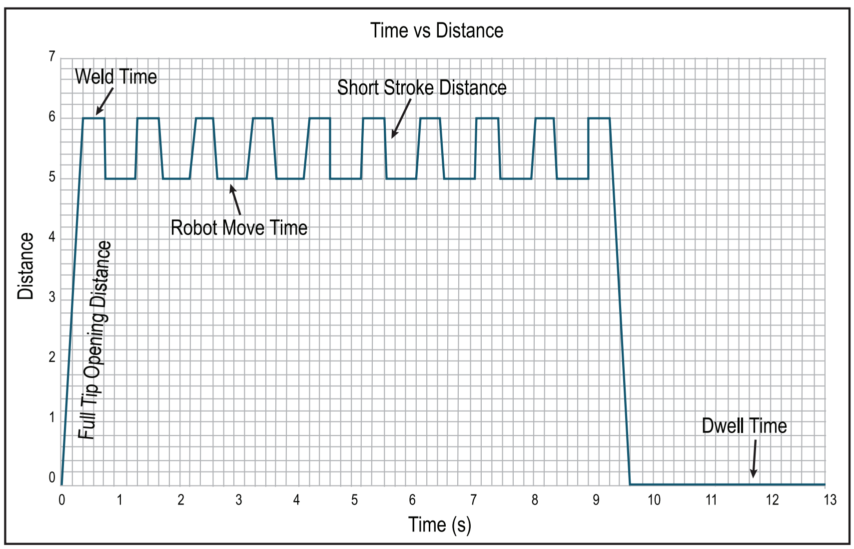
A machine builder selecting an actuator must take many factors into account including load, repeatability, and facilities and maintenance costs.

Selecting an Actuator Type

When developing a pressing system for production use in automobile manufacturing lines, the machine builder needs to maximize throughput and performance while minimizing cost. The dilemma engineers face with traditional fixed fluid power actuators is that each production line has different needs which drive different requirements from the pressing system. For example, one application may use a press system to pressure test transmission cavities while the same basic system could also be used to press bearings into vehicle axles. Each of these processes require different motion profiles, and the actuator system must be able to adapt accordingly.

Another automotive press system example is a robotic weld gun. The robot first locates the weld gun in position relative to the automobile frame. Then, the actuator closes the weld tips together against the two parts to be welded. After closing, the press operation clamps the component parts together with a pre-specified force during the weld cycle. When the weld is completed, the weld tips need to open rapidly for the robot to move to the next weld position.

Weld Gun Press Motion Profile



The motion profiles of real-world automobile manufacturing robotics like weld guns are much more complex than a simple open-and-close press cycle.

A common motion profile for a press cycle starts with the press fully open to permit unloading and loading of parts. Following this, the actuator must rapidly close toward the freshly loaded part. Inertia and speed are the two main concerns during this move, but the goal is to move as quickly as possible to maintain production efficiency. After closing, the pressing operation is accomplished which requires low speed, high force, and high accuracy. Finally, the press should rapidly open, with minimal concern for accuracy, to load the next part.

With these disparate profiles, each actuator type has its advantages and disadvantages. Pneumatic actuators are well suited for the high speed, low accuracy portions of the motion profile, but they do not generate enough force for the pressing cycle. Hydraulic actuators perform admirably during the high force press segment of the motion profile, but lack the speed and efficiency desired during the open and close cycles.

In contrast, electromechanical actuator solutions hold a unique advantage over traditional fluid power actuators; they can produce the force necessary for high force pressing as well as move quickly enough to keep up with high rate production.

In addition, by pairing a servo motor with the electromechanical actuator, a machine builder can reap the benefits of closed-loop control. This motion control method allows for high accuracy and repeatability resulting in superior finished part quality, such as more consistent welds and properly seated bearings.

Electromechanical actuators can be easily programmed for different pressing modes. For instance, a press-to-position mode tells the controller to continue the pressing motion until a precise position has been reached. Press-to-force lets the controller continue the motion until a certain force is returned as feedback, for instance when a ball bearing bottoms out on its race during a press operation. In addition, electromechanical actuators can be quickly programmed with new motion profiles as manufacturing requirements change or if rapid part changeover is required.

Electromechanical actuators with integrated motors can fit the footprints of the hydraulic cylinders they are replacing. Other designs permit bolt-on motors or integrate drivers as well.

Sizing an Actuator

Combining high force, high speed, and long life requires unique rating methods to ensure the selected actuator meets each of the performance requirements at an affordable cost. In pressing applications, the motion profile typically calls for high-speed moves along with short, high force pressing moves. Rating methods differ between fluid power actuators and electromechanical actuators.

Fluid power actuator ratings are typically provided by the cylinder manufacturer in terms of length of travel or hours of operation at specified pressures and speeds. These cylinders should be selected such that they can handle the pressure necessary to produce the desired force, run at speeds required by the application, and produce an acceptable lifetime for the pressing operation. Hydraulic actuator lifecycles are usually constrained by wear on cylinder components like seals and scrapers. Consequently, the life spans of these actuators greatly depend on environmental factors like cleanliness. In pressing applications, these actuators can be rated for upwards of 1 million cycles.

Unlike fluid power actuators, electromechanical actuator life is estimate using L_{10} life calculations common to the roller bearing industry. This rating method is utilized as screw type actuators have operational methods that are analogous to ball bearings, given that they are mechanical in nature and involve rolling contact. While it is not an exact science, the L_{10} calculation provides a means for machine builders to develop a life estimate for electromechanical actuators.

As with any mechanical device, life calculations are only theoretical, and all actuators should be tested in the application before entering production with a new machine. Please visit www.exlar.com for a ***further explanation*** of life expectancy for electromechanical roller screw actuators.

Industry Trends

The automotive industry is trending towards sustainability, not only with their vehicles, but also with their methods of vehicle production. With sustainability in mind, most manufacturers are moving towards environmentally friendly electric systems and away from fluid power systems which are susceptible to leaking.

In press manufacturing such as axle bearing installation, new high-force electric solutions are available, allowing automotive manufacturers to fully realize their vision of sustainable and environmentally friendly manufacturing. Current factories in North America are retooling to increase production efficiency, improve safety, and lower maintenance.

Until recently, fluid power actuators have been the de facto standard in press systems; pneumatics for high-speed, low-force applications and hydraulics for high-force, low-speed applications. On the lower force applications, ball screw actuators have been slowly replacing pneumatics as the industry transfers to electric solutions. High force applications have been slower to convert to electric solutions, as economical electromechanical actuators in similar package sizes to hydraulic actuators have been difficult to come by. As actuator manufacturers continue to innovate and develop new high force electromechanical actuators, vehicle manufactures will soon turn to fully electric systems for all of their “pressing” needs.