Drive & Control
profile

Electric, Hydraulics, Pneumatics: Evaluating Their Advantages for Automotive Manufacturing Processes

A body paint shop is an example where advantages of multiple technologies can be applied: the paint supply is controlled with proportional pneumatics; the paint color is selected by pneumatics, while the paint spraying robots are electrically controlled.

In the highly competitive automotive manufacturing market companies are looking not only to machinery and automation that decreases cycle times, but also at technology to reduce downtime, provide easier setup and simplify operator interfacing.

The choice of using electric, hydraulic, or pneumatic motion systems is a fundamental decision that affects performance, costs, maintainability, safety, ease of use, flexibility, and reliability. Each discipline clearly has areas where it excels enough to be the obvious choice. In others, the needs of the application and the capabilities of the technology must be carefully evaluated—and then balanced with a cost-benefit analysis.

While there are numerous factors involved in selecting a technology, begin by concentrating

In Search of Impartial Advice?

Most vendor-supplied technology recommendations should often come with a *caveat emptor* warning, especially if the company specializes in one technology.

Companies that embrace electric, hydraulic and pneumatic motion technologies are positioned better to give unbiased advice and help customers achieve the best solution for performance and price. The company should have strong product portfolios in all three disciplines, but also have considerable expertise in integrating electric, hydraulic and pneumatic technologies into an overall solution.

A cross-technology company will consider the application, evaluate different approaches, and recommend the best solution for a wider range of options and flexibility in choices.

on some key areas: accuracy and repeatability, complexity of the application, speed, flexibility, reliability and maintainability (R&M), and life cycle costs. Start with a broad generalization about the primary application using these three technologies, knowing that many exceptions exist and that many applications embrace more than one technology. *(see Figure 1)*

Basic Comparison

	Hydraulic	Electric	Pneumatic
Working Speed (velocity)	5 m/s	10 m/s	4 m/s
Power Density	High	Low	Low
Achievable Force	High	High	Limited, ~20 kN
Achievable Stroke	High, to 10m+	High	High, to 10M+
Change Of Forces	Simple and accurate	Simple to complex	Simple and accurate
Efficiency	Best	Good	Good
Connections	Simple	Simple	Very simple
Overload Safety	Complete	Complete	Complete
Explosion Proof	Available	Available	Yes

Figure 1

Electric control excels when absolute accuracy of movement is required or when continuous motion is needed. Electric servo control is useful in such diverse applications as CNC spindle controls in machining centers and in lift and locate applications in assembly operations.

Electric servo control is useful in such diverse applications as CNC spindle controls in machining centers like this crankshaft grinder.

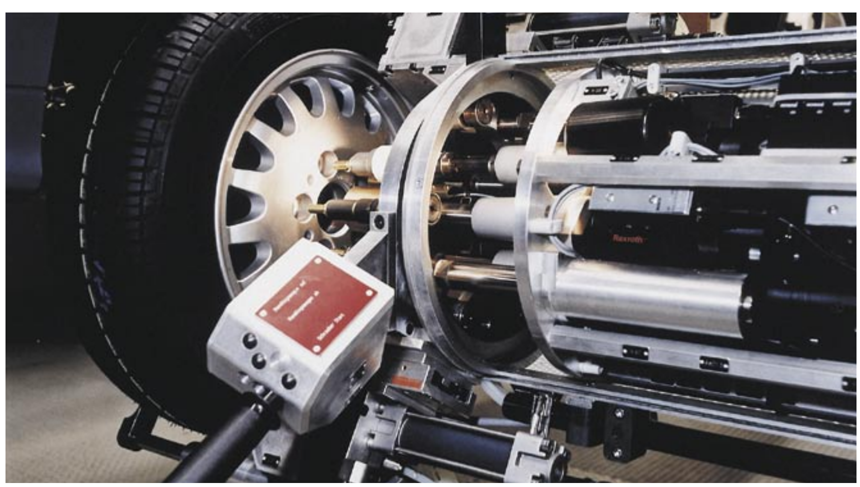
Hydraulics is the choice for heavy loads when immediate motion is required. Forces are by far the highest of the three technologies—upwards of 100 tons. Hydraulics allows full velocity to be achieved quickly.

Pneumatics is chosen because speed and force are easily and continuously controllable over a wide range. This technology is also functionally reliable under adverse operating conditions and insensitive to external influences such as high and low temperatures, dirt, mechanical vibration, moisture, and electrical noise. Pneumatics finds wide use in automotive assembly lines, body shops, and paint shops. In addition, pneumatics is intrinsically safe.

Since they use cylinders, hydraulic and pneumatic applications achieve linear motion simply and easily. Electric control, by virtue of being motor driven, is based on rotating motion and requires a transition—such as ball screw or linear motor.

Accuracy and Repeatability

In comparing fluid power to electric control, the degree of accuracy and repeatability must be considered. Precision includes both the accuracy of positioning and repeatability. In many cases, if the motion only requires two or three



Electronic servo control gives a high level of precision. In wheel mounting, feedback on the torque applied to the nuts is easily obtained to ensure an evenly distributed torque pattern for proper tightening.

positions, fluid power is extremely accurate and repeatable. For more than three positions, pneumatics can give about +/-1mm.

Electronic servo control offers the highest levels of precision, particularly in closed-loop applications where feedback allows the system to adjust to conditions. For example, Bosch Rexroth offers the System 300 advanced DC tightening system which allows for multi-stage programming and multiple synchronization of the spindle motors. During wheel mounting, feedback on the torque applied to the nuts is easily obtained to ensure an evenly distributed torque pattern for proper tightening.

Some applications may allow options to choose between two technologies. An example from Bosch Rexroth is their identically sized servo pneumatic and servo electric cylinders for the control of resistance welding guns in automotive welding and assembly lines. For either system the choice between the two is often determined by the process in which it will be used, with consideration given to response time to adjust tip pressures, clamping forces, speed of clamping, and similar issues. The use of electric control is ideal for response time to adjust tip pressures and allows for constant pressure monitoring. In addition, electric control allows for integrated adaptive control. Pneumatic control provides a natural spring. In welding applications where cavities exist between two imperfect sheets of metal, the natural spring of

Bosch Rexroth has developed identical-sized servo pneumatic and servo electric cylinders for the control of welding guns in automotive welding and assembly lines. For either system the choice between the two is often determined by the process in which it will be used.

compressed air compensates the tip position very quickly to collapse the cavity as the metal heats up.

Today's hydraulic and pneumatic valves allow greater control than previous generations. A servo valve

Closed-loop control is now possible with pneumatics and hydraulics. The Bosch Rexroth IAC-R hydraulic valve with closed-loop position and pressure control takes advantage of decentralized intelligence for hydraulic drive technology.

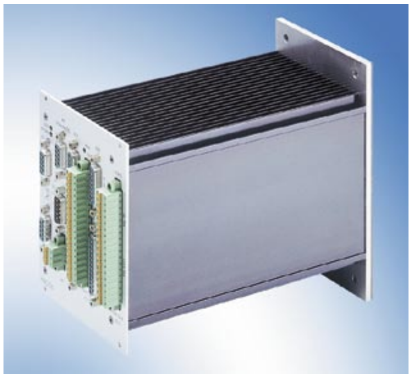
uses linear changes in current to provide changes in the air or oil pressure or flow through the valve. Proportional and servo valves use position feedback to the valve amplifier to achieve linear operation. Motion control systems using hydraulic power rely on proportional, servo-proportional, or servo valves to control position, pressure, and velocity.

While fluid power has traditionally been used in open-loop applications, today's systems also incorporate closed-loop operation. With closed-loop control, precision hydraulic and pneumatic components incorporating digital electronics have made these systems more competitive with electrical closed-loop systems.

An area where fluid power excels is in its ability to apply constant pressure efficiently—for example, in holding a load in a certain position. The advantage is that fluid power can maintain constant pressure without consuming additional energy. An electric motor achieves constant pressure by applying constant torque. Holding the torque requires continuous power.

Complexity of the Machine

Hydraulic servo-based digital control is ideal for complex multi-axis applications, particularly those requiring a high degree of synchronization. For example, in flow forming machines (which make transmission clutch housings), hydraulics provides the force but digital electronics allow for the control. The electronic controller takes



Intelligent digital control, such as the HNC 100 hydraulic controller from Bosch Rexroth, allows for applications with more sophisticated hydraulics.

particular characteristics of the hydraulics into consideration and compensates for their effects by using the delay error emitted by the NC and a speed signal taken from the directional measuring system.

Servo-based electric control is also ideal in applications requiring tight synchronization, such as the installation of wheels onto vehicles. By using servo-based tightening the user is able to synchronize multiple axes (multiple times) to allow for constant pressure even for insertion of the wheel bolts. Servo control can also replace traditional mechanical camming and linkages with their electronic counterparts. The reduction in mechanical parts offers several advantages in achieving accuracy and repeatability: mechanical parts are subject to wear and require periodic adjustment.

Pneumatics finds wide application in machining applications by offering fine performance and simple application. At high axis counts, however, servo control becomes more attractive. One reason is the ease with which electronic digital intelligence can be applied to an application, either from a centralized controller or by distributing intelligence outward into the drives and even motors. Coupled with high-speed protocols like SERCOS, which was specifically designed to control high-axis-count servos applications, electronic motion and control allows sophisticated synchronization.

Pneumatics and hydraulics benefit from increased intelligence and the ability to communicate directly with factory-level protocols. Bosch Rexroth, for example, introduced what is believed to be the first Ethernet/IP-equipped pneumatic valve manifold used in automotive manufacturing—in a destacker used to feed blanks into a stamping machine. In many material handling applications, using a vacuum is the best method to handle lightweight or delicate components like windscreens or body panels. Therefore, the ability to be able to communicate in industry-standard protocols makes it easier to integrate pneumatics, and hydraulics, into an application. Pneumatic and hydraulic fieldbus valve manifolds reduce wiring complexity by combining the communication interface with the I/O components and connecting the controller over a single wire.

This Rexroth Series 261 pneumatic manifold is EtherNet/IP-equipped, making it easier to integrate into an application.

Intelligent digital control brings hydraulics and pneumatics to new levels of control, enabling more sophisticated application than earlier generations. The benefit is not only more precise control, but programmability to allow application changes to be easily accomplished.

Productivity

Productivity, in part, relies on increasing throughput and decreasing the cycle time of machines. Of course, there are technical and economic limitations to achieving faster throughput. In basic terms, the three technologies offer a practical working speed for simple linear motions as follows:

- **Electric:** 10 meters per second
- **Hydraulics:** 5 meters per second (assuming not using a motor)
- **Pneumatics:** 4 meters per second (assuming not using a motor)

Pneumatics has emerged as the medium of choice for productivity in the spray painting of vehicles, mainly because pneumatics is intrinsically safe. Electro-pneumatic pressure control valves control the speed of rotary sprayers as well as air and paint volumes, providing constant pressure needed to achieve accurately distributed paint application.

Flexibility

Servo systems are well known for allowing setup parameters to be easily changed so that the system can handle multiple configurations or jobs with changes only to the control program. Pre-packaged and customized application programs make tooling changeovers fast and easy. And since mechanical parts are replaced by electronic counterparts, the time required to change from one job to another is minimized significantly. With pneumatics, generally most plants have compressed air and most pneumatic drives and valve manifolds are inherently modular, thereby enabling future expansion.

In all parts of automotive assembly, the need for more production flexibility is increasingly important to help companies lower their costs and remain competitive. One example of such flexibility is the Bosch Rexroth Programmable Lift Platform (PLP) which makes it easier for a machine builder to develop and commission lift equipment in welding, assembly, and other automotive manufacturing lines. The PLP is essentially a servo-driven, three-axis Cartesian robot with a small footprint on the factory floor. It's an economical alternative to the traditional custom pallets. The goal is to allow different auto bodies to be processed on the same line without shutting it down to reset between body types. The platform has the ability

The PLP is a servo-driven, three-axis Cartesian robot that serves as an economical alternative to traditional custom pallets.

to move locking pin points to adjust to different component sizes. Changes in production runs are accomplished through pre-programmed automated adjustments, eliminating the need for time-consuming mechanical changeovers.

Reliability and Maintainability (R&M)

Reliability (probability of a failure) and Maintainability (how fast to repair, clear, etc.) and diagnostics are all factors to consider in evaluating which technology to use. Great progress has been made in materials such as hydraulic cylinder seals, which now offer extremely long lives to help improve R&M. In machining centers, where metal chips are a by-product of production, pneumatics can be "self-cleaning," used to blow away chips and debris.

Advanced diagnostics and predictive maintenance have also advanced considerably for all three technologies. Properly designed machines have the ability to monitor their own operation, detect changes, and warn operators of impending problems. Corrective actions can be taken to prevent major downtime and expensive repairs. Such advanced diagnostics are well known for electronic controls, but the same capabilities are found today in hydraulic and pneumatic systems. One example is the Drive & Diagnostic Link (DDL) from Bosch Rexroth. Providing connectivity with all major fieldbus protocols, including ControlNet, DeviceNet, Ethernet-IP, Interbus S and PROFIBUS, the DDL is a complete control system for pneumatic valves, electrical to pressure pneumatic control valves, process valves, and I/O modules. It features diagnostic information down to the solenoid level. The DDL continuously checks each valve for the following:

- Supply voltage tolerances on electronics power
- Supply voltage tolerances on valve/communication power
- Solenoid coil opens or shorts
- Short circuits

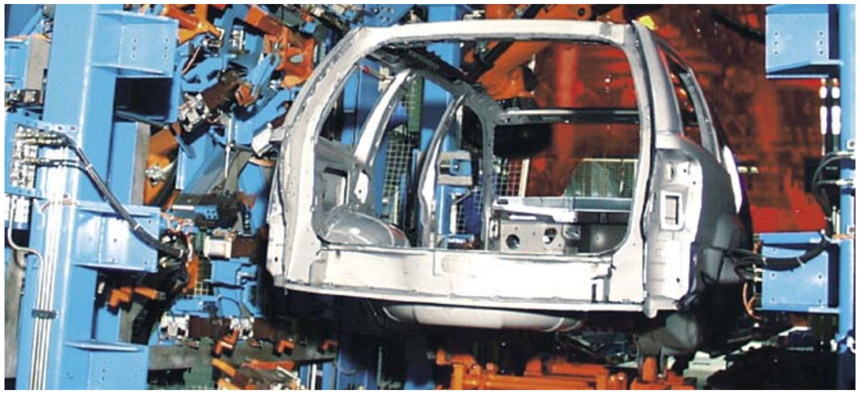
The DDL provides real-time monitoring of voltage levels and reports if the voltage falls out of tolerance. Because the DDL can report this information for each valve or sensor over the fieldbus the PLC can provide much richer information on fault causes and remedies, including advanced predictive diagnostics.

Life Cycle Costs (LCC)

As with any application, both acquisition costs and lifecycle costs must be considered in choosing the most suitable technology. Acquisition costs are fairly straightforward: how much does it cost to procure and apply the components into the application.

For life cycle costs, the customer needs to look at the design, build and operating costs. Regardless of evaluating electric, hydraulic or pneumatic motion system options, it's important to remember that the Life Cycle Cost Impact Analysis requires additional time and resources in the concept and design stages. This effort will produce the lowest operating cost for a particular system or component.

When evaluating electric, hydraulic or pneumatic systems, consideration should also be given to the flexibility of the selected technology to ensure you're not locked into a dead-end solution for future needs. In a time of fierce competition and tight budgets, automotive companies are finding novel ways of extending equipment life and lowering the costs of upgrades and new equipment. Often, the basic electric, hydraulic, pneumatic drive and control components can be reused or adapted to changing application needs with significant cost savings.



Pneumatics finds wide use in automotive assembly lines, body shops and paint shops.

The other cost issue is energy costs. Generalizations are dangerous here, because energy costs must be evaluated with respect to larger factory-level energy use issues. Savings at one point might increase costs at another point so that a narrowly focused approach may prove inadequate.

The Real World: Mixed Technologies Rule

Many automotive applications are not limited to a single technology. Instead, they take advantage of the unique characteristics of each technology. For example, the destacker mentioned earlier uses both servo drives and pneumatics from Bosch Rexroth to position 22 different blank configurations precisely for feeding the stamping machine.

A body paint shop is another example of applying different technologies to obtain the advantages of each. The paint supply is typically controlled with proportional pneumatics, while the robots spraying the paint are electrically controlled.

Conclusion

As always, careful evaluation of alternatives is essential to picking the best technology. Past experience isn't a good indicator of present and future capabilities for electric, hydraulic or pneumatic control. Closed-loop control—once seen as the special advantage of electric control—is now possible with hydraulics and pneumatics. Indeed, electropneumatics and electrohydraulics have raised the capabilities beyond the deterministic bang-bang operation of yesteryear. Talk to suppliers, integrators, and others to make sure you fully understand the capabilities and tradeoffs each technology offers.

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