Fluid Power Basics

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The term fluid power refers to energy that is transmitted via a fluid under pressure. With hydraulics, that fluid is a liquid such as oil or water. With pneumatics, the fluid is typically compressed air or inert gas. Fluid power's motive force comes from the principle that pressure applied to a confined fluid is transferred uniformly and undiminished to every portion of the fluid and to the walls of the container that holds the fluid. A surface such as a cylinder piston will move if the difference in force across the piston is larger than the total load plus frictional forces. The resulting net force can then accelerate the load proportionately to the ratio of the force divided by the mass.

Fluid power advantages

Fluid power is used in a diverse range of applications from mobile construction and aerospace equipment to powering industrial machinery, and offers several advantages over other types of motive force.

With fluid power systems, a single source of fluid pressure (compressor or pump) can power many axes or fluid power devices. The power source can be located where space is not critical. Because much of the size and weight of the fluid power system is off-loaded onto the power unit, the individual actuators can be small compared to the power they produce. In addition, they are often quieter, and generate less heat than electric actuators. Fluid power actuators can also be used in hazardous environments where electric sparks must be avoided

By using accumulators to store energy, the hydraulic power unit only needs to provide slightly more than the average demand, increasing efficiencies for machines with varying load cycles.

In applications such as presses where a constant holding pressure or torque must be applied, hydraulic actuators have a big advantage because no energy is used while they are not moving, whereas a motor draws a large amount of current to maintain torque even while stopped. Most motors will overheat and fail under these conditions.

Hydraulic cylinders are very smooth and efficient for linear movement. There are no poles that cause cogging and no need for backlash compensation.

Tradeoffs between hydraulic vs. pneumatic power

Though hydraulic and pneumatic power share many characteristics in common, there are some key differences. For example, because hydraulic fluid is much less compressible than a gas, hydraulic power is preferred over pneumatic when precise position control is required. On the other hand, pneumatic power has an edge in applications where the presence of hydraulic oil could cause problems (e.g. in food processing machines). Pneumatic systems are also typically less expensive to build than hydraulic.

Designing a fluid power system

The design of a hydraulic or pneumatic power circuit and selection and physical placement of the components in the system are critical to maximizing the performance of fluid power systems. Figure 1 shows a typical hydraulic system with electronic motion controller. Following is a discussion of key system elements.

Pumps

Pumps supply the oil or air under pressure that is required to move the system's cylinder pistons, converting mechanical power to fluid power. Usually only one pump is required to power all the cylinders in the system and it only needs to large enough to supply the average amount of oil required by the application per machine cycle. This assumes that accumulators are properly sized and precharged so they can store the oil or air under pressure when the system is not moving. Undersized pumps will result in a system that can not move at desired speed or decelerate to a target position quickly because of lack of controlling pressure. Oversized hydraulic pumps are wasteful as they cost more and require that oil be bypassed to the storage tank when the system is not moving.

Cylinders

The cylinder converts fluid power to linear mechanical power (in rotary fluid power applications, the cylinder would be replaced by a motor). Just as the right size hydraulic or pneumatic pump is critical, so are correctly sized cylinders. Increasing the size of a cylinder increases natural frequency of operation and allows it to accelerate faster, at the cost of requiring larger valves and pumps than smaller cylinders used in non-speed-critical applications.

Accumulator

Accumulators are energy storage devices, reservoirs for air or oil pressure. For best results, use accumulators of adequate size and place them close to the valves. Accumulators serve two important functions. First, they store energy so that the pumps do not have to be sized for peak loads. Second, they keep the system pressure relatively constant if sized correctly. This is important when using a motion controller because the PID gains should change as a function of the system pressure. Therefore keeping the system pressure constant reduces the need to change gains as a function of pressure in the motion controller. Keeping the pressure relatively constant also provides for smoother motion when moving slowly. Over-sized pumps do not replace accumulators. If there is more than one actuator (valve/cylinder combination) in the system, consider peak loading when sizing the accumulator.

Plumbing

Solid piping rather than hose should be used between the valve and the cylinder, since hoses contract and change shape and any change of area affects controllability. Keep pipes as short and straight as possible, as pressure drops occur in bends. Place the valves on the cylinders or as close a possible to the cylinders in order to keep the volume of oil or gas between the valve and cylinder as small as possible. This helps keep the natural frequency of the systems as high as possible.

Valves

For high-performance motion, use linear valves with zero overlap. They can be either servo valves or servo-quality proportional valves. A valve that uses most of its range is generally easier to control, so choose the response time and flow rates that match the application, avoiding grossly over-sized valves. The valves are called “zero overlap” because there's no “dead zone” between active control ranges (ranges that increase or decrease fluid pressure). Valves with overlap may be advantageous for manually controlled systems, but not for high performance, high precision position/pressure systems.

Motion Controller

The oldest and least sophisticated hydraulic or pneumatic systems employed on/off control of pressure valves, sometimes called “bang-bang” valving because of the “jerkiness” of motion that discrete control causes. New systems are designed for smooth, accurate motion using variable valves controlled by electronic motion controllers. Electronic motion controllers can be set up to employ sophisticated predictive control algorithms, using inputs from both position and pressure sensors to provide tighter control and more flexibility than was previously possible with hydraulic control elements. By building in special smart functions, controller manufacturers can offer higher productivity to machine builders.

An example is the RMC100 controller family from Delta Computer Systems that can execute high-level commands such as spline functions (see figure 2). Using splines, implementing smoothly curving motion that carries a hydraulic or pneumatic actuator from one coordinate position to the next is as simple as connecting the dots. The motion profiles can be developed graphically and actual motion can be compared to target motion profiles via the motion controller’s development software such as Delta’s RMCWin software. Splines can also be used to linearize a nonlinear motion such as a cylinder rod pushing on a rotating arm.

Another selection criteria to keep in mind when choosing a motion controller is to make sure that it interfaces easily to other computing elements that may be in the system, such as programmable logic controllers (PLCs), industrial computers or human-machine interfaces (HMIs). New controllers have fieldbus interfaces: standardized, high-performance connections such as Ethernet and Profibus. Make sure the motion controller supports not only the proper electrical connections, but is also certified specifically for compatibility with the modules to which it connects.

Sensors/Transducers

The motion controller gets its position and pressure inputs from transducers that are mounted in the cylinders (linearly actuated systems) or via encoders that are mounted on axes (rotational systems). Look for motion controllers that provide direct interfaces to transducers. Pressure transducers in linear activation systems are typically mounted on either side of the piston (see Figure 1) so that they measure differential pressure. To measure linear position, many systems use magnetostrictive displacement transducers (MDTs), which have the advantage of not requiring a homing step.

Performance, precision, and price make fluid power the right choice

Hydraulic and pneumatic power offer many advantages over electric motors, especially for systems that require high-speed linear travel, moving or holding heavy loads, or very smooth position or pressure control. Compared to other types, hydraulic and pneumatic actuators are smaller and quieter. They also produce less heat and electromagnetic interference (EMI) at the machine than do electric actuators, and in many cases, in particular with high-performance hydraulic or pneumatic systems, they offer the ability to build machines at considerable savings compared to machines employing purely electrical or mechanical motion.

By selecting appropriate system components and programming the appropriate motion control algorithms, the result can be a system that offers high performance and very precise motion at a reasonable cost. For more information on the subject of fluid power, check out the web site of the National Fluid Power Association (www.nfpa.com). For more information on motion controllers appropriate for use with fluid power, see the web site of Delta Computer Systems, Inc. (deltacompsys.com).

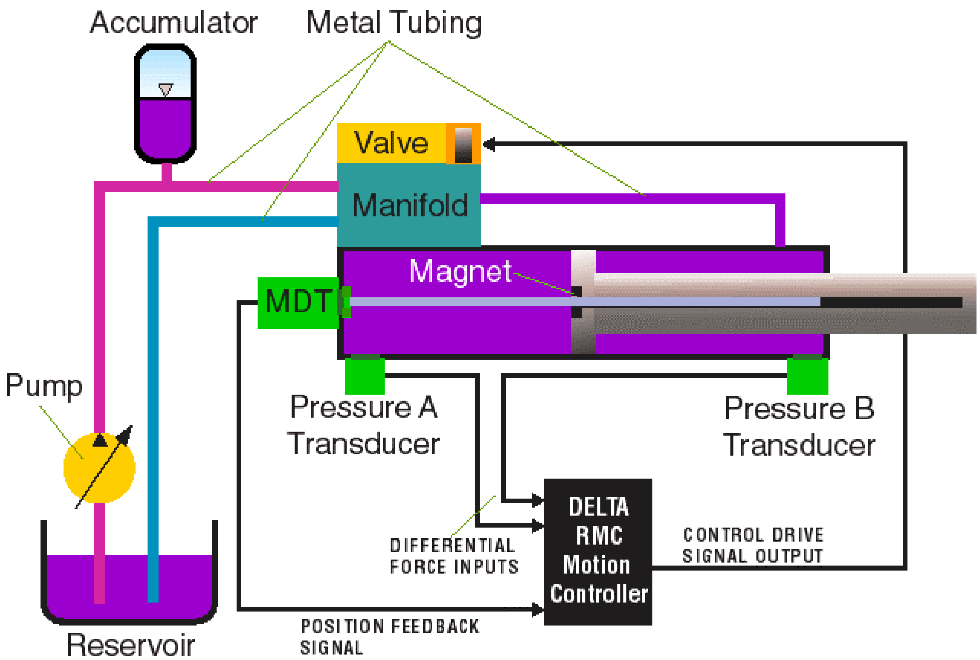

Figure 1. Fluid Power Control System (hydraulic)

Figure 2. Typical Motion Controller