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Hydraulic and Pneumatic Control in Mechatronics Systems (Article Review)

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ABSTRACT
Hydraulic and pneumatic control play an important role in mechatronic systems. Selection of control devices in designing mechatronic systems that uses hydraulic or pneumatic circuits studied by many researchers. A description of both hydraulic and pneumatic theory is introduces comparing between hydraulic and pneumatic systems based on their applications, used fluid, advantages and disadvantages and functions. Also, comparison between different power systems showing the difference between them in power source, cost, uses, affected parameters and advantages and disadvantages is studied. the importance of using hydraulic and pneumatic systems in different fields of industry is introduced.

Keywords: *hydraulic, pneumatic, power systems*

• Introduction

In the Mechatronics systems, three methods for transmitting power from one point to another are used. Mechanical transmission is through shafts, gears, chains, belts, etc. Electrical transmission is through wires, transformers, etc. Fluid power is through liquids or gas in a confined space. Hydraulics is the term concerned with fluid mechanics (the branch of science which deals with the behavior of fluids at rest as well as in motion). Pneumatics is the branch of engineering that makes use of gas or pressurized air. Both hydraulics and pneumatics are applications of fluid power (Joseph A. Schetz *et al*). In the fluid power applications, fluids are used for the generation, control, and transmission of power using pressurized liquids. Fluid can define as a substance which can flow and does not maintain its shape for a long time. Fluids can take the shape of the container depending on the surroundings and flow in a large area when the surrounding removed. In addition, a fluid is a substance that continually deforms under applied shear stress. Fluids are a subset of the phases of matter and include liquids, gases, plasmas, and to some extent, plastic solids. Fluid such as water is using for the conversion of hydraulic energy into mechanical energy to do some useful work. In the heating, ventilation, and air-conditioning industry (HVAC), the liquid such as water is using for transmission of heat from one area to another. The fluid is a primary element of a hydraulic system, which obeys Pascal's law to give fluid power.

The advantages of Hydraulics can be summarized as:

- In general, it is simple, safe, and economically easier to maintain. Hydraulic systems use fewer moving parts in comparison with mechanical and electrical systems.
- Compared to pneumatics it is highly responsive and supplies more power than pneumatics.
- The liquid does not absorb any of the supplied energy.
- Using simple levers and push buttons, it can be easily controlled. The operator of a hydraulic system can easily start, stop, speed up and slow down.

The example of Hydraulics systems is Jaws of Life, dump truck lifts, water guns, forklifts, cranes etc.
Pneumatic is the branch of physics or technology concerned with the mechanical properties of gases. Pneumatic can also be defined as a branch of fluid power in which use gas as a fluid. There are two types of gases are used in pneumatic systems such as compressed air and Nitrogen. Compressed air is a mixture of all gases contains in the atmosphere. The unlimited supply of air and the ease of compression make compressed air the most widely used fluid for pneumatic systems.
In the pneumatic system simply, the air is used to transmit energy. The air has greater supply everywhere. When air is compressed, it can be used to perform work.
Pneumatics is the most widely applied fluid power technology. In the pneumatic system compressed air acts as both a working and control medium.
The use of pneumatic or compressed air has many advantages of transmitting energy and control functions in the system.
Some of the main advantages of pneumatic systems as follow:

- Availability of air.
- The compressibility of air.
- Compressed air is easy to transport in pressure vessels, containers and pipes.
- Simple in construction and easy to handle.
- Controlling the ability to pressure, speed and force is high.
- Maintenance is low.
- Explosion-proof characteristic of the medium.
- Cost is low as compared to other systems.
- Fire-proof characteristic of the medium.
- Possibilities of easy but reliable in remote controlling.

Some of the important applications of the pneumatic systems are:

- Using for packing.
- Using for filling.
- In drilling, hoisting, punching, clamping, assembling, riveting.
- Opening and closing the doors.
- Used in industrial robots.
- For power hammers and nut runners
- Used in riveting hammers.
- Using for braking system in automobiles, railway coaches, wagons and printing presses.
- Used in metal forming processes.
- Used in material handling types of equipment and logic controlling operations

Pneumatic and hydraulic systems have been used for many years within industrial processes and as such has acquired an established place in the modern industry.
In hydraulics and pneumatics, hydraulics is liquid while pneumatics is gas and the main difference between these two is, Hydraulic systems use liquids like water and oil to transmit power. Where pneumatic systems use air to transmit power. In hydraulics, liquids are relatively incompressible. Liquids have high specific mass and have a free surface. A tank is used to store the oil. In pneumatics, gases are readily compressible. They have a very low specific mass and gases do not have a free surface. In a pneumatic system, air can simply be drawn from the environment and purified using a filter.
Hydraulic systems are used for high force and where stiffness in position is necessary. They move relatively slowly but can handle higher loads. The installation is complex, and the maintenance cost is high.
Pneumatic systems are used for relatively lower forces, faster motion, and where stiffness isn't required. They have a very controlled force, regardless of stroke or load resistance. Installation of this system is less complicated and have less.

• FLUID POWER AND ITS SCOPE

Fluid power is the technology that deals with the generation, control and transmission of forces and movement of mechanical element or system with the use of pressurized fluids in a confined system. Both liquids and gases are considered fluids. Fluid power system includes a hydraulic system and a pneumatic system. Oil hydraulic employs pressurized liquid petroleum oils and synthetic oils, and pneumatic employs compressed air that is released to the atmosphere after performing the work. Fluid power applications can be classified into two major segments:
Stationary hydraulics: Stationary hydraulic systems remain firmly fixed in one position. The characteristic feature of stationary hydraulics is that valves are mainly solenoid operated. The applications of stationary hydraulics are as follows:

- Production and assembly of vehicles of all types.
- Machine tools and transfer lines.
- Lifting and conveying devices.
- Metal-forming presses.
- Plastic machinery such as injection-molding machines.
- Rolling machines.
- Lifts.
- Food processing machinery.
- Automatic handling equipment and robots

2.1. Mobile hydraulics: Mobile hydraulic systems move on wheels or tracks such as a tower crane or excavator truck to operate in many different locations or while moving. A characteristic feature of mobile hydraulics is that the valves are frequently manually operated. The applications of mobile hydraulics are as follows:

- Automobiles, tractors, airplanes, missile, boats, etc.
- Construction machinery.
- Tippers, excavators, and elevating platforms.
- Lifting and conveying devices.
- Agricultural machinery

Hydraulics and pneumatics have almost unlimited application in the production of goods and services in nearly all sectors of the country. Several industries are dependent on the capabilities that fluid power affords.
The hydraulic systems can be classified as two types (R.B. WALTERS):

2.2. Fluid transport systems: Their sole objective is the delivery of a fluid from one location to another to accomplish some useful purpose. Examples include pumping stations for pumping water to homes, cross-country gas lines, etc.

2.3. Fluid power systems: These are designed to perform work. In fluid power systems, work is obtained by pressurized fluid acting directly on a fluid cylinder or a fluid motor. A cylinder produces a force resulting in linear motion, whereas a fluid motor produces a torque resulting in rotary motion.
The fluid power system can be categorized as follows:

2.4. Based on the control system
Open-loop system: There is no feedback in the open system and performance is based on the characteristics of the individual components of the system. The open loop system is not accurate, and error can be reduced by proper calibration and control.
Closed-loop system**:** This system uses feedback. The output of the system is fed back to a comparator by a measuring element. The comparator compares the actual output to the desired output and gives an error signal to the control element. The error is used to change the actual output and bring it closer to the desired value. A simple closed-loop system uses servo valves, and an advanced system uses digital electronics.

Based on the type of control
Fluid logic control: This type of system is controlled by hydraulic oil or air. The system employs fluid logic devices such as AND, NAND, OR, NOR, etc. Two types of fluid logic systems are available:
(a) Moving part logic (MPL): These devices are miniature fluid elements using moving parts such as diaphragms, disks, and poppets to implement various logic gates.
(b) Fluidics: Fluid devices contain no moving parts and depend solely on interacting fluid jets to implement various logic gates.
Electrical control: This type of system is controlled by electrical devices. Four basic electrical devices are used for controlling the fluid power systems: switches, relays, timers, and solenoids. These devices help to control the starting, stopping, sequencing, speed, positioning, timing, and reversing of actuating cylinders and fluid motors. Electrical control and fluid power work well together where remote control is essential.
Electronic control: This type of system is controlled by microelectronic devices. The electronic brain is used to control the fluid power muscles for doing work. This system uses the most advanced type of electronic hardware including programmable logic control or microprocessor. In the electrical control, a change in system operation results in a cumbersome process of redoing hardware connections.

The difficulty is overcome by programmable electronic control. The program can be modified, or a new program can be fed to meet the change of operations. A number of such programs can be stored in these devices, which makes the systems more flexible.

- **Hydrostatic and Hydrodynamic Systems**

A hydrostatic system uses fluid pressure to transmit power. Hydrostatics deals with the mechanics of still fluids and uses the theory of equilibrium conditions in fluid. The system creates high pressure, and through a transmission line and a control element, this pressure drives an actuator (linear or rotational). The pump used in hydrostatic systems is a positive displacement pump. The relative spatial position of this pump is arbitrary but should not be very large due to losses (must be less than 50 m). An example of pure hydrostatics is the transfer of force in hydraulics. Hydrodynamic systems use fluid motion to transmit power. Power is transmitted by the kinetic energy of the fluid. Hydrodynamics deals with the mechanics of moving fluid and uses flow theory. The pump used in hydrodynamic systems is a non-positive displacement pump. The relative spatial position of the prime mover (e.g., turbine) is fixed. An example of pure hydrodynamics is the conversion of flow energy in turbines in hydroelectric power plants. In oil hydraulics, we deal mostly with the fluid working in a confined system, that is, a hydrostatic system.

- **Fluid Power**

Fluid power is as old as our civilization itself. Water was used for centuries to produce power by means of water wheels and air was used to turn windmills and to propel ships. Chinese used wooden valves to control water flow through bamboo pipes in 4000 BC. Ancient Egyptians have built a masonry dam across Nile, 14 miles south to present Cairo, for the control of irrigation water by canals, sluices, brick conduits and ceramic pipes. During the Roman empire, extensive water systems using aqueducts, reservoirs and valves were constructed to carry water to cities. However, these early uses of fluid power required the movement of huge quantities of fluid because of the relatively low pressures provided by nature. Fluid power technology began in 1650 with the discovery of Pascal's law. Simply stated, this law says that pressure in a fluid at rest is transmitted undiminished equally in all directions in a confined body of fluid. Pascal found that when he rammed a cork down into a jug completely full of wine, the bottom of the jug broke and fell out. However, for Pascal's law to be made effective for practical use, it was necessary to make a piston that would fit exactly. Not until over 100 years later was this accomplished. It was in 1795 that Joseph Brahmah invented the cup packing that led to the development of a workable hydraulic press. Brahmah's hydraulic press consisted of a plunger pump piped to a large cylinder and a ram. This new hydraulic press found wide use in England because it provided a more effective and economical means of applying large force to industrial applications.

In 1750, Bernoulli developed his law of conservation of energy for a fluid flowing in a pipeline. Both Pascal's and Bernoulli's laws operate at the heart of all fluid power applications and are used for analytical purposes. However, it was not until the Industrial Revolution of 1850 in Great Britain that these laws were applied to the industry. The first use of a large hydraulic press for foregoing work was made in 1860 by Whitworth. In the next 20 years, many attempts were made to reduce the waste and excessive maintenance costs of the original type of accumulator. In 1872, Rigg patented a three-cylinder hydraulic engine in which provision was made to change the stroke of plungers to vary its displacement without a throttle valve. In 1873, the Brotherhood three-cylinder, constant-stroke hydraulic engine was patented and was widely used for cranes, winches, etc. Both the above-mentioned engines were driven by fluid from an accumulator. Up to this time, electrical energy was not developed to power the machines of industry. Instead, fluid power was being used to drive hydraulic equipment such as cranes, presses, shearing machines, etc. With electricity emerging dominantly in the 19th century, it was soon found superior to fluid power for transmitting power over great distances. The modern era in fluid power began around the turn of the century. Fluid applications were made to such installations as the main armament system of USS Virginia in 1906. In these applications, a variable-speed hydrostatic transmission was installed to drive the main guns. Since that time, marine industry has applied fluid power to cargo-handling systems, controllable pitch controllers, submarine control system, aircraft elevators, aircraft- and missile-launching system and radar/sonar-driven systems. In 1926, the United States developed the first unitized, packaged hydraulic system consisting of a pump, controls, and an actuator. Today fluid power is used extensively in practically every branch of industry. The innovative use of modern technology such as electrohydraulic closed loops, microprocessors and improved materials for component construction continues to advance the performance of fluid power systems. The military requirements kept fluid power applications and developments going at a good pace. Aviation and aerospace industry provided the impetus for many advances in fluid power technology

- **Advantages of a Fluid Power System**

Oil hydraulics stands out as the prime moving force in machinery and equipment designed to handle medium to heavy loads. In the early stages of industrial development, mechanical linkages were used along with prime movers such as electrical motors and engines for handling loads. But the mechanical efficiency of linkages was very low, and the linkages often failed under critical loading conditions. With the advent of fluid power technology and associated electronics and control, it is used in every industry now.

The advantages of a fluid power system are as follows:

5.1. Fluid power systems are simple, easy to operate and can be controlled accurately:
Fluid power gives flexibility to equipment without requiring a complex mechanism. Using fluid power, we can start, stop, accelerate, decelerate, reverse, or position large forces/components with great accuracy using simple levers and push buttons. For example, in Earth-moving equipment, bucket carrying load can be raised or lowered by an operator using a lever. The landing gear of an aircraft can be retrieved to home position by the push button.

5.2. Multiplication and variation of forces:
Linear or rotary force can be multiplied by a fraction of a kilogram to several hundreds of tons.

5.3. Multifunction control:
A single hydraulic pump or air compressor can provide power and control for numerous machines using valve manifolds and distribution systems. The fluid power controls can be placed at a central station so that the operator has, at all times, a complete control of the entire production line, whether it be a multiple operation machine or a group of machines. Such a setup is more or less standard in the steel mill industry.

- *Low-speed torque:* Unlike electric motors, air or hydraulic motors can produce a large amount of torque while operating at low speeds. Some hydraulic and pneumatic motors can even maintain torque at a very slow speed without overheating.
- *Constant force or torque***:** Fluid power systems can deliver constant torque or force regardless of speed changes.
- *Economical:* Not only reduction in required manpower but also the production or elimination of operator fatigue, as a production factor, is an important element in the use of fluid power.
- *Low weight to power ratio:* The hydraulic system has a low weight to power ratio compared to electromechanical systems. Fluid power systems are compact.
- Fluid power systems can be used where safety is of vital importance: Safety is of vital importance in air and space travel, in the production and operation of motor vehicles, in mining and manufacture of delicate products. For example, hydraulic systems are responsible for the safety of takeoff, landing and flight of airplanes and space craft. Rapid advances in mining and tunneling are the results of the application of modern hydraulic and pneumatic systems.
- **Basic Components of a Hydraulic System**

Hydraulic systems are power-transmitting assemblies employing pressurized liquid as a fluid for transmitting energy from an energy-generating source to an energy-using point to accomplish useful work. Figure 1 shows a simple circuit of a hydraulic system with basic components.

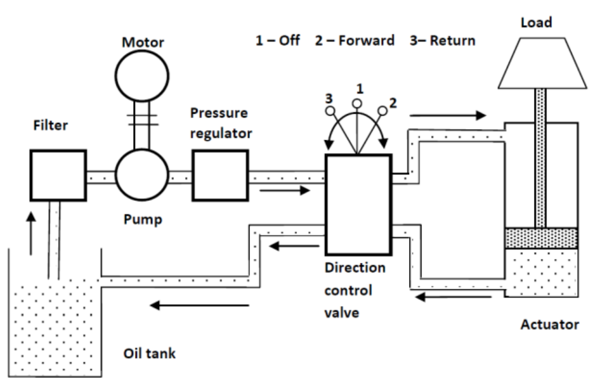

Fig.1 Components of a hydraulic system

Functions of the components shown in Fig. 1 are as follows:

- The hydraulic actuator is a device used to convert the fluid power into mechanical power to do useful work. The actuator may be of the linear type (e.g., hydraulic cylinder) or rotary type (e.g., hydraulic motor) to provide linear or rotary motion, respectively.
- The hydraulic pump is used to force the fluid from the reservoir to rest of the hydraulic circuit by converting mechanical energy into hydraulic energy.
- Valves are used to control the direction, pressure and flow rate of a fluid flowing through the circuit.
- External power supply (motor) is required to drive the pump.
- Reservoir is used to hold the hydraulic liquid, usually hydraulic oil.
- Piping system carries the hydraulic oil from one place to another.

- Filters are used to remove any foreign particles so as keep the fluid system clean and efficient, as well as avoid damage to the actuator and valves.
- Pressure regulator regulates (i.e., maintains) the required level of pressure in the hydraulic fluid.

In industry, a machine designer conveys the design of hydraulic systems using a circuit diagram. Figure 2 shows the components of the hydraulic system using symbols. The working fluid, which is the hydraulic oil, is stored in a reservoir. When the electric motor is switched ON, it runs a positive displacement pump that draws hydraulic oil through a filter and delivers at high pressure. The pressurized oil passes through the regulating valve and does work on actuator. Oil from the other end of the actuator goes back to the tank via return line. To and from motion of the cylinder is controlled using directional control valve.

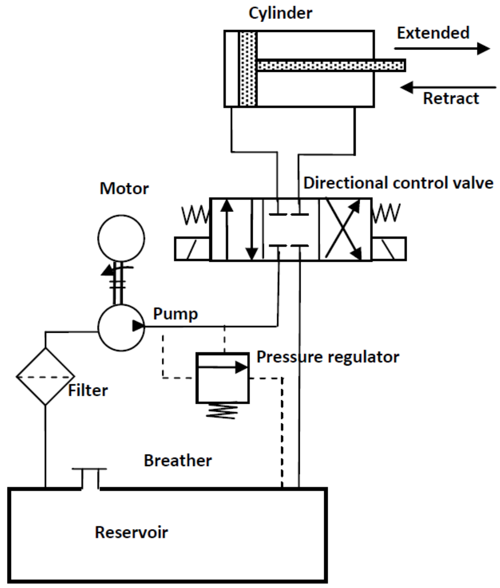

Fig.2 Components of a hydraulic system using symbols

The hydraulic system discussed above can be broken down into four main divisions that are analogous to the four main divisions in an electrical system.

- The power device parallels the electrical generating station.
- The control valves parallel the switches, resistors, timers, pressure switches, relays, etc.
- The lines in which the fluid power flows parallel the electrical lines.

The fluid power motor (whether it is a rotating or a non-rotating cylinder or a fluid power motor) parallels the solenoids and electrical motors

- **Basic Components of a Pneumatic System**

A pneumatic system carries power by employing compressed gas, generally air, as a fluid for transmitting energy from an energy-generating source to an energy-using point to accomplish useful work. Figure 3 shows a simple circuit of a pneumatic system with basic components.

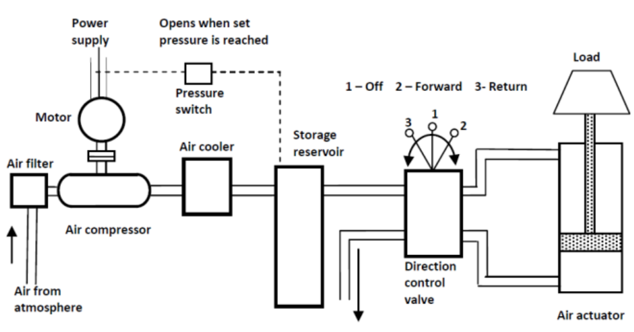

Fig.3 Components of a pneumatic system.

The functions of various components shown in Fig. 3 are as follows:

- The pneumatic actuator converts the fluid power into mechanical power to perform useful work.
- The compressor is used to compress the fresh air drawn from the atmosphere.
- The storage reservoir is used to store a given volume of compressed air.
- The valves are used to control the direction, flow rate and pressure of compressed air.
- External power supply (motor) is used to drive the compressor.

The piping system carries the pressurized air from one location to another.

- **Comparison between Hydraulic and Pneumatic Systems**

Usually hydraulic and pneumatic systems and equipment do not compete. They are so dissimilar that there are few problems in selecting any of them that cannot be readily resolved. Certainly, availability is one of the important factors of selection, but this may be outweighed by other factors. In numerous instances, for example, air is preferred to meet certain unalterable conditions, that is, in “hot spots” where there is an open furnace or other potential ignition hazard or in operations where motion is required at extremely high speeds. It is often found more efficient to use a combined circuit in which oil is used in one part and air in another on the same machine or process. a brief comparison of hydraulic and pneumatic systems can be summarized as.

Table1

Comparison between a hydraulic and a pneumatic system

Hydraulic System	*Pneumatic System*
It employs a pressurized liquid as a fluid	It employs a compressed gas, usually air, as a fluid
An oil hydraulic system operates at pressures up to 700 bar	A pneumatic system usually operates at 5–10 bar
Generally designed as closed system	Usually designed as open system
The system slows down when leakage occurs	Leakage does not affect the system much
Valve operations are difficult	Valve operations are easy
Heavier in weight	Lighter in weight
Pumps are used to provide pressurized liquids	Compressors are used to provide compressed gases
The system is unsafe to fire hazards	The system is free from fire hazards
Automatic lubrication is provided	Special arrangements

The difference between hydraulic and pneumatic systems can be summarized as:

Table2

Difference between a hydraulic and a pneumatic system

Hydraulic systems	*Pneumatic systems*
Hydraulics uses liquids like water or oil	Pneumatics uses compressed gas like air
Liquids are incompressible, high specific mass and have a free surface	Gases are readily compressible, have very low specific mass and do not have free surface
Hydraulic systems are used for high force and where stiffness in position is necessary. They move relatively slowly but can handle higher loads.	Pneumatic systems are used for relatively lower force, faster motion and where stiffness isn’t required
The installation is complex and maintenance cost is high	Installation of the system is less complicated and have less maintenance cost
The tank is used to store oil from which the system can draw oil in case of deficit.	The system can just draw air from the atmosphere and just a filter would be required to purify it
Liquids are not very compressible, that there is no delay in the movement	Because gas can be compressed, there is a delay in the movement
Examples of use: Vehicle brakes, Jacks, Forklift, Cranes, Jaws of lift, Hydraulic lift, etc.	Examples of use: Pneumatic air brakes, Actuators, Jackhammer, etc.

- **Comparison of Different Power Systems**

There are three basic methods of transmitting power: electrical, mechanical, and fluid power. Most applications use a combination of the three methods to obtain the most efficient overall system. To properly determine which method to use, it is important to know the salient features of each type. For example, fluid systems can transmit power more economically over greater distances than mechanical types. However, fluid systems are restricted to shorter distances compared to electrical systems. Table 1 lists the salient features of each type

Table3

Comparison of different power systems

Property	*Mechanical*	*Electrical*	*Pneumatic*	*Hydraulic*
Input energy source	I C engines Electric motor	I C engines Water/gas turbines	I C engines Pressure tank	I C engines Electric motor Air turbine
Energy transfer element	Levers, gears, shafts	Electrical cables and magnetic field	Pipes and hoses	Pipes and hoses
Energy carrier	Rigid and elastic objects	Flow of electrons	Air	Hydraulic liquids
Power-to-weight ratio	Poor	Fair	Best	Best
Torque/inertia	Poor	Fair	Good	Best
Stiffness	Good	Poor	Fair	Best
Response speed	Fair	Best	Fair	Good
Dirt sensitivity	Best	Best	Fair	Fair
Relative cost	Best	Best	Good	Fair
Control	Fair	Best	Good	Good
Motion type	Mainly rotary	Mainly rotary	Linear or rotary	Linear or rotary

• **Control components in Hydraulic system**

One of the most important functions in any fluid power system is control (Robert H. Bishop *et al*). If control components are not properly selected, the entire system will fail to deliver the required output. Elements for the control of energy and other control in fluid power system are generally called “Valves”. It is important to know the primary function and operation of the various types of control components. This type of knowledge is not only required for a good functioning system, but it also leads to the discovery of innovative ways to improve a fluid power system for a given application The selection of these control components not only involves the type, but also the size, the actuating method and remote-control capability. There are 3 basic types of valves.

10.1. Directional control valves

Directional control valves are essentially used for distribution of energy in a fluid power system. They establish the path through which a fluid traverses a given circuit. For example, they control the direction of motion of a hydraulic cylinder or motor. These valves are used to control the start, stop, and change in direction of flow of pressurized fluid. Directional control valves can be classified as:

- *According to type of construction:*
  - Poppet valves
  - Spool valves
- *According to number of working ports:*
  - Two- way valves
  - Three – way valves
  - Four- way valves.
- *According to number of Switching position:*
  - Two – position
  - Three - position
- *According to Actuating mechanism:*
  - Manual actuation
  - Mechanical actuation
  - Solenoid (Electrical) actuation
  - Hydraulic (Pilot) actuation
  - Pneumatic actuation
  - Indirect actuation

10.2. Pressure control valves

Pressure control valves are usually named for their primary function such as relief valve, sequence valve, unloading valve, pressure reducing valve and counterbalance valve.

- Pressure Relief valve

- Unloading Valve
- Sequence valve
- Counterbalance Valve
- Pressure Reducing Valve

*10.3. Flow control valves***.**

The valves which are mainly used to regulate the flow of fluid in hydraulic circuits are known as "flow control valves". The flow control valves are widely available in many different types according to their use.

- Gate valve
- Plug valve
- Needle valve
- Non-return valve
- Butterfly valve
- Pressure compensated flow control valves
- Pinch valve
- Globe valve
- Diaphragm valve
- Ball valve

- **Applications in mechatronics systems**

- Hydraulic-pneumatic hybrid powertrains provide an opportunity for combined high power and high energy regenerative braking systems for heavy duty vehicles that need to transpose both highway and urban areas. The challenge in designing these systems resides in the proper sizing, integration, and control of the components to exploit with high efficiency the different energy and power range available in these applications. Bravo *et al*, (Rafael Rivelino Silva Bravo *et al*) presented a new concept of a hydraulic-pneumatic system for braking energy recovery in heavy-duty vehicles which was recovered by a hydraulic system and stored in a hydraulic accumulator and in an air reservoir. While the hydraulic system shares the vehicle propulsion in parallel to the internal combustion engine, the compressed air is used to power auxiliaries in power-assist mode. The conception, modeling, sizing, and system integration are presented, relying on commercially available components. The lumped parameter simulation model written in MATLAB/Simulink is first validated by comparing measurements and predictions for a laboratory system. Then, two conditions of braking energy recovery for a 19 tons bus are analyzed: a full stop, typical of urban driving, and a downward road slope, typical of highway driving. Results indicate that the system proposed is able to store 69% of the available energy during full stop and 14% in the highway downward slope. However, although the storage efficiency is smaller in the downward slope, the total energy recovered is 2.8 times larger than the energy recovered after full stop. Also, while the pneumatic energy stored is only 20% of the energy stored in the hydraulic accumulators after full stop, it is more than twice for the road slope. These results indicate an opportunity for significantly improving the overall energy efficiency of delivery trucks and buses.
- (Laukenmann *et al)* proposed two types of clutch controllers that prepare the clutch and track a prescribed torque trajectory. These controllers are used in a hybrid dual-clutch transmission to improve the performance and comfort of the hybrid modes.
- (Gomis-Bellmunt *et al*) discussed the optimization of linear hydraulic actuators. The procedure presented has been employed to obtain the maximum energy and force in a given volume, weight or cross-section. The scalability of the analyzed actuators has been also discussed.
- (Papoutsidakis *et al*) presented bibliographic research on the main applications of these two systems, analyzing their components and operation. Moreover, deepening on pneumatic systems, focused on one of the most modern pneumatic machines in food packaging: the Tetra Pak's A6. This machine is the first and only device in the world capable of packing UHT milk in one-liter aseptic carton bottles. The 10 steps required by the machine to fulfil its function, was examined in detail, alongside with its connections, sensors and controllers.
- (Jun Han *et al*) choosed variable displacement motor as the driving unit for underwater winch. Based on that, a complete hydraulic control circuit was proposed. The oil circuit could realize the active cable picking and laying automatically. Meanwhile, the motor could be adjusted with infinitely variable speed function. In order to save energy, an automatic unloading circuit was designed. At the same time, considering the complex underwater working environment and bad working conditions, hydraulic clutch was introduced to increase the function of cable passive releasing. The hydraulic circuit had fast response and high fault tolerance, which not only ensures the underwater winch to complete various operations quickly and effectively, but also ensures the safety of all parts of the winch.

- (Figliolini *et al*) designed of a novel robotic hand, cassino-underactuated-multifinger-hand (Ca.U.M.Ha.) which is designed with four identical underactuated fingers and an opposing thumb, all joined to a rigid palm and actuated by means of double-acting pneumatic cylinders. In particular, each underactuated finger with three phalanxes and one actuator is able to grasp cylindrical objects with different shapes and sizes, while the common electropneumatic operation of the four underactuated fingers gives an additional auto-adaptability to grasp objects with irregular shapes. Moreover, the actuating force control is allowed by a closed-loop pressure control within the pushing chambers of the pneumatic cylinders of the four underactuated fingers, because of a pair of two-way/two-position pulse-width modulation (PWM) modulated pneumatic digital valves, which can also be operated under ON/OFF modes
- (Gao *et al*) proposed a novel single-stage high-pressure electro-pneumatic servo valve (HESV) directly driven by a voice coil motor (VCM) for a precision control system. The HESV was a three-position three-way spool-type flow valve. The aerostatic bearing was designed to reduce the friction wear and improve the motion sensitivity of the spool. A nonlinear mathematical model of the HESV was derived including the electromagnetic subsystem, dynamic force balance equation. Furthermore, considering the highly nonlinear steady gas flow force, a hybrid fuzzy logic PID controller with a disturbance observer (DOB) was adopted to improve the performance of the HESV. A numerical analysis and experiments were carried out, and their results indicate that the static friction force of the developed HESV decreases from 15 N to 4.4 N because of the aerostatic bearing. The developed HESV exhibits a strong anti-interference performance because of the hybrid controller with the DOB; the valve spool could be recovered to the original control position rapidly within 0.03 s. The position control accuracy of the novel HESV was greatly improved. Thus, the HESV could be applied to high-pressure pneumatic precision control systems.
- Sorting of objects or materials is very essential in almost any Industry, and by doing in a proper way saves time and increases overall productivity. Human errors like misplacing, procedures not followed, and lack of attention can also be a problem and that’s why there is an intervention of smart robots in Industry. Advanced robots are used is in the manufacturing industry. Robots have been a boom to the manufacturing industry. Most industrial robots work in auto assembly lines, hazardous places. Robots can do repetitive work more efficiently than human beings because they are so fast and precise. (Sughashini *et al*) programmed a pneumatic Robot arm which can sort some objects taking advantage of the information contained. These systems can be used in several applications from food industry to automobile industry. The Aim of the project was to separate the objects from a set according to their color. This project could be modified in which servo motors and image processing cameras can be used in order to achieve repeatability and accuracy. This application could be used in Food industry, Automobile industry and almost every manufacturing unit.
- Hydraulics is a promising technology for robots. However, traditional hydraulic infrastructures are often large and power-inefficient, with large power sources that hinder mobility. In contrast, electro-hydrostatic actuators are relatively power efficient, but their cost and weight can be excessive in systems with a higher number of degrees of freedom. (Kittisares *et al*) proposed a new alternating pressure control system for hydraulic systems with a higher number of degrees of freedom based on an alternating pressure source system. In this system, the valves were opened and closed in synchronization with a pump with sensor feedback, allowing either pressure or position in each actuator to be controlled independently. With the proposed system, a centralized pump can be used with simplified tubing and simple on–off valves. Moreover, a dynamic duty ratio system that improves performance and reduces pump utilization time is developed. The experimental results confirmed that both the position and pressure of each actuator can be controlled in parallel on a multi-degree-of-freedom system
- The applications of fluid power technology in the U.S. are widespread and diverse. A primary disadvantage of fluid power systems is their low energy storage density. Flywheels are robust, aligning naturally with hydraulic systems’ strengths, and offer up to an order of magnitude higher specific energy than hydraulic accumulators. The hydraulic flywheel accumulator is a dual domain energy storage system that leverages complimentary characteristics of each domain. The system involves rotating a piston style accumulator about its axis to store kinetic energy as well as pneumatic energy. The pneumatic energy is stored in the inner radii of the flywheel which do not lend themselves to efficient kinetic energy storage. Also, the centrifugal effects on the fluid will tend to mitigate the pressure dependent state of charge issue of traditional pneumatic accumulators. (Cronk *et al*) modeled and optimized a system for laboratory scale, constructed, and tested in a laboratory hardware-in-the-loop hydraulic system. Through prototype construction and experimentation, the concept was shown to be feasible, and the energy loss models were shown to accurately predict the system performance.

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Conclusion

Hydraulic and pneumatic control systems have a wide range of applications in mechatronic systems. So, it attracts all researchers to understand and compare hydraulic and pneumatic control systems to reach the appropriate selection of control devices in designing mechatronic systems that uses hydraulic or pneumatic circuits. In this study, a description of both hydraulic and pneumatic theory is summarized. A comparison between hydraulic and pneumatic systems based on their applications, used fluid, advantages and disadvantages and functions are introduced. A comparison between different power systems is clarified showing the difference between them in power source, cost, uses, affected parameters and advantages and disadvantages. A survey in applications of hydraulic and pneumatic systems in designing mechatronic projects is introduced showing the importance of using these systems in different fields of industry.

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