Module-01 : INTRODUCTION TO HYDRAULIC AND PNEUMATIC SYSTEMS

Lecture-01 : What is Hydraulic and Pneumatic System:

Fluid power systems use fluids to transmit power and motion. Both liquids and gases are called fluids. Hence both these types of fluids are used in fluid power technology. Under liquids mostly mineral oil with suitable additives are used instead of plain water - (which, however, is used also in some cases) and under gases usually atmospheric air is used after cleaning it suitably. However, synthetic fluids with additives and other gasses are also used for specific purposes, such as fire resistance or the fluid itself is the product- milk as an example. That is the state of art behind these two modern technologies of industrial oil-hydraulics and pneumatics.

Fluid power technology actually has a long history behind it. From early days of civilization mankind could feel the existence of power in the water currents of rivers and streams, in ocean waves and in the flowing breeze and in the turbulent storms. Early men could even harness some of these natural sources of energy. Wind energy, for example, was utilized in sailing boats and water current to drive water wheels. Hydroelectric power generation still uses the same idea, of course now-a-days in a much more efficient way.

Fluid power technology in its earliest forms mostly took advantage of the motion of fluids or scientifically speaking of its kinetic energy. But the present day oil hydraulics mostly depends on the pressure-energy of the fluids rather than its velocity and in some cases it is even called as hydrostatic transmission of power.

A historical background of the development of this subject is summarized in Chart-1. The development of this idea owes a lot to the seventeenth century French scientist Pascal and his famous law on transmissibility of fluid pressure equally in all directions (Pascal's Law 1650 : "Pressure in a fluid at rest is transmitted equally in all directions"). This did not evoked much the growth of Fluid Power nearly a century until Bernoulli (1750) established the law of Conservation of Energy in fluid mechanics.

However, idea of Power Transmission by Fluid Power was put in engineering practice more than hundred years later after Pascal by the Englishman Bramah who showed in his own hydraulic press (1800) how out of a relatively small effort on a long stroke, small diameter piston a very large force on a short stroke large diameter piston could be produced. It also showed at the same time a means of power transmission over medium distances by first converting mechanical power into hydraulic power and then finally reconverting hydraulic power back into mechanical power. Pressurized liquids could transfer energy from one point to another by getting conveyed through flexible pipes which could bend round corners.

Chart-1:

History of development of Fluid Power

1800	Branch	Power transmission by water; Hydraulic Press; Leather cup Seal technology
1900		
1910	Constaninesco	First ideas of Alternating Flow Hydraulics (AFS)
1920	Hele Shaw Beachan	
1930	Thomas Dowty	High Pressure Vane pumps; Synthetic rubber seals
1940		Electro hydraulic servos & rubber sac accumulators
1950	MIT Labs	Hydraulics & Pneumatics; Hot gas servos
1960	Growing research effort throughout Industry, universities & Technical colleges. Power Station.	Air fluidics; Digital hydraulics, oil fluidics
1980		oil hydraulics; Micro process and computer controlled
2000	Rapid growth in Electronics and Manufacturing	Hybrid Systems; Energy Saving System
2010	Technology	Wide application of proportional valves.
	Nano Technology	Micro-hydraulic system; Nano Fluidics.

The simplicity and ease of using hydraulic power was greatly appreciated and around 1860 London and Manchester had central fluid power generating stations to pump energized fluids to various factories. This tendency, however, got checked somewhat towards the end of the nineteenth century by the emergence of electrical power transmission. A brief comparison on fluid, electrical and mechanical power transmission is summarized in Chart- 2 .

Chart -2

Advantages and disadvantages of Fluid Power Transmission over Mechanical and Electrical Power Transmissions are briefly as follows.

Advantage	Disadvantage
1. Material medium - heat dissipation,	1. Messy in general.
2. Inertia to turque ratio	2. Leakages control is a problem
3. Mechanically Stiff ↑ (Oil hydraulic)	3. Bursts of hose, pipe line 4. Fire hazard & Explosion may occur.
4. High attainable speed response.	5. Contamination control is a problem
5. The same medium can be used for both drive as well as control.	

Fluid power technology revived again the mid twentieth century because of certain inherent advantages. The high force-to-weight ratio of hydraulic devices makes its use very attractive especially in situations where weight is at a premium such as aircrafts and missiles. The limitation of electro-magnetic devices is the magnetic saturation of the iron core which puts a serious natural limitation to its capability. A hydraulic device on the other hand can work at a very high pressure and so its size can be kept small.

The very large force capability still remains one of the big advantages of Hydraulics and Hydraulic servomechanism uses this property. Hydraulic rams and presses are quite well known.

For transmission of power over a distance usually four elements are necessary. First is the pump which is invariably of the positive displacement type and whose function is to transform mechanical input power which drives it into hydraulic output power. The second element is the Hydraulic motor or Actuator, which converts the hydraulic energy back into useful mechanical energy at the point of application. The motion of this element may be reciprocating rectilinearly or over small arcs or it can be a continuous rotation usually with directional reversibility. In between the pump and motor the fluid has to be conveyed through pipes of suitable strength and dimensions and this is the third element. The fourth element is the controlling element which is usually called the valve and it may control pressure, flow and direction of the fluid and can be used by an operator or can work automatically under given conditions. Of course, a suitable reservoir for hydraulic fluid is also a necessity - as the fluid is re-circulated in the system after repeated cleaning and cooling.

Pneumatic systems work in similar ways. When air is used as working fluid it can be exhausted in the atmosphere without bothering for re-circulation. The working pressure in pneumatic systems, (max 7 to 10 bar), however, is much lower than hydraulic pressures (300 bar or more) necessitating larger piston areas to develop a large force.

As mentioned earlier, the control of fluid power systems is done usually by valves. However, a modern method has emerged since about 1958 where the controlling action is performed by one fluid jet acting on another fluid stream or jet. These pure fluid devices are called "Fluidic" or "Flueric" devices - the word "Fluidic" being a combined word out of the two words "Fluid" and "Logic". This technology is more suitable for pneumatic applications and that also under low pressure. For higher pressures valves with moving elements are more suitable.

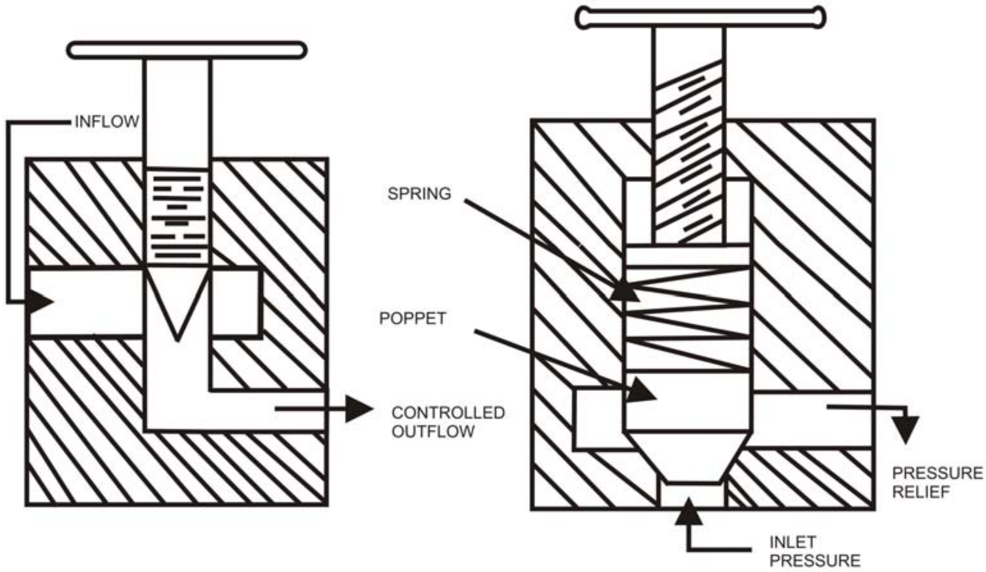
Basically valves and Fluidic devices may be also called switches. And as one of the main functions of a switch is to put ON and OFF power, it can be used as a two-state device with outputs ON or OFF, or in terms of binary systems 1 or 0, or in terms of symbolic logic true or false. This makes it possible to use the switching circuit algebra (also known as "Logic circuit algebra" or "Boolean Algebra") which electrical engineers use in the design of telephone exchanges and computer switching circuits - in fluid power technology as well without at all bothering to interface with electrical elements.

In this way non-contact sensing using pure fluid devices is possible and in many sequence controlled machines and automatic handling and inspection systems these devices are getting more and more applications. This has made a considerable impact on fluid circuit design methods as well.

At this stage a closer look on the problem of control of fluid power seems quite in order. From knowledge of mechanics it is well known that :

Power = force x velocity = pressure x area x velocity = pressure x flow rate

Hence fluid power control involves control of pressure and flow rate. By using a variable restrictor in the passage of the fluid flow rate can easily be controlled (See Fig. 1).



(Schematic View)

Fig.- 1 : Flow Control Valve Fig.- 2 : Direct Pressure Relief Valve

For controlling the pressure in a system, say, for keeping it below a safe pressure and arrangement is shown in Fig.2, where the poppet valve is kept under variable spring pressure to put a stop to the flow. When the pressure exceeds the spring pressure the poppet gets lifted and pressure is relieved (controlled).

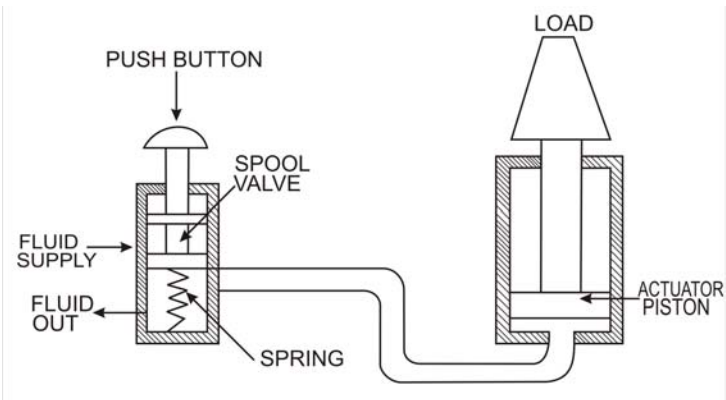


Fig. -3 : A simple Fluid Power System (Application Example)

A spool type valve is often used for controlling flow and direction. An example of a simple fluid power application is shown in Fig.3, where the push button (which is controlled by an operator) allows the working fluid to enter the actuator cylinder as to exhaust out of it. Pushing the button down makes the load rise up. Lift alone by itself the valve spring pushes up the valve and the fluid comes out of the working cylinder to exhaust, bringing the load down. The valve is controlling here the movement of the load but an accurate movement of the load through definite distances is not ensured here automatically. A skilled operator can achieve that knowing the system characteristic and/or an accurate calibration curve. Such type of controlling is known as 'open loop control'.

If, however, the movement of the load (output) was made to act upon the controlling valve (input) to get a desired output it would be a 'closed loop' control. In order to let the output be monitored continuously with the input, a 'feedback' loop is needed.

The concept is represented in block diagram as follows (Fig. 4):

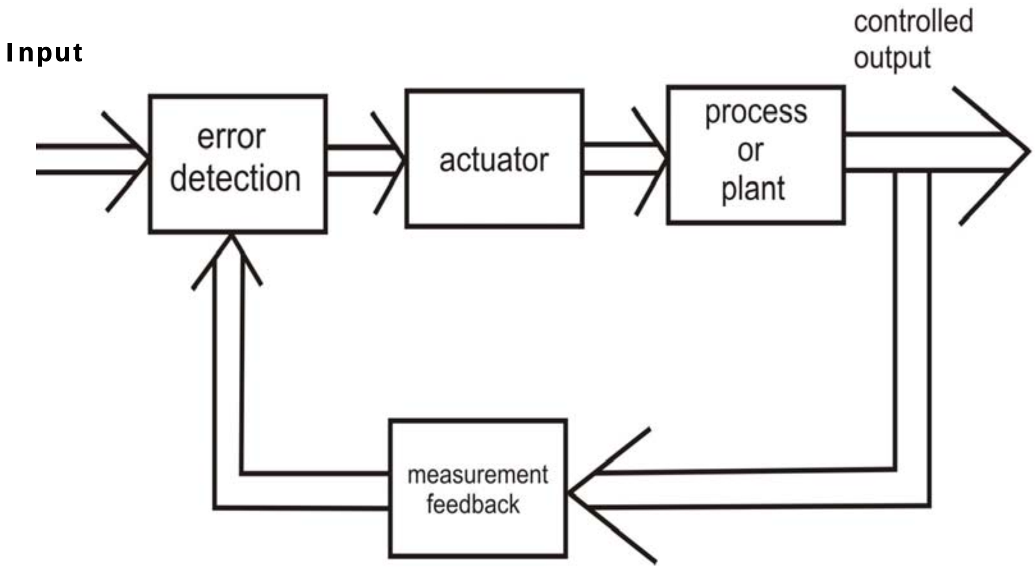


Fig. -4 : Block diagram of a feedback control system.

A schematic sketch of a typical hydraulic servomechanism is shown in Fig.5 which is an example of this.

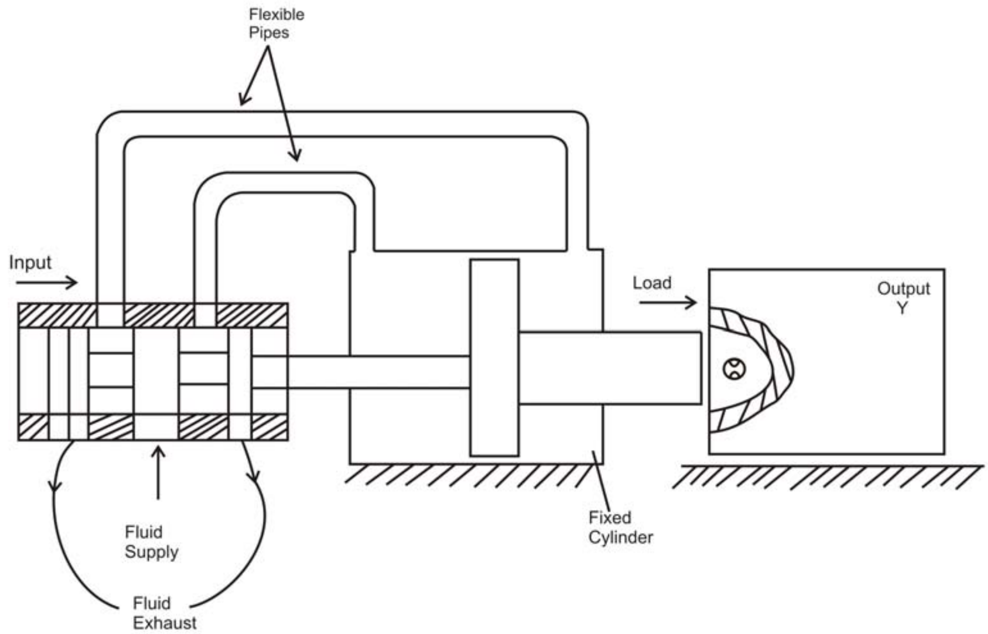


Fig.- 5 : Hydraulic Servomechanism (Schematic Diagram)

An input effort X, say, from left to right will produce a large force output to move the load through a distance Y proportioned to X. In a copy lathe, for example, the input X would be generated by a template follower and the output Y would be the cutting tool position for reproducing the template shape.

Here the valve is doing the output measurement and error detection and also it is supplying the corrective power to the working cylinder.

In many systems the control arrangement required may not be aimed to do only a particular simple operation, but to control sequences of operations. Such sequence controls may be 'event based' or 'time based'. When a particular action takes place only when the previous event has been completed, it is an 'event based' sequence. But when a number of events are ordered to be completed according to a definite programmed time interval irrespective of the completion of other events, it is a 'time based' sequence.

This introduction to the subject of fluid control will be closed with an example of an event-based sequence operated by fluid control as illustrated in Fig.6. The system here is used for lifting an object from one conveyor level to another, automatically without any human intervention. The sequence of operations consists of first extension of cylinder rod A and then B and then A and B retract and wait for the next object to come.

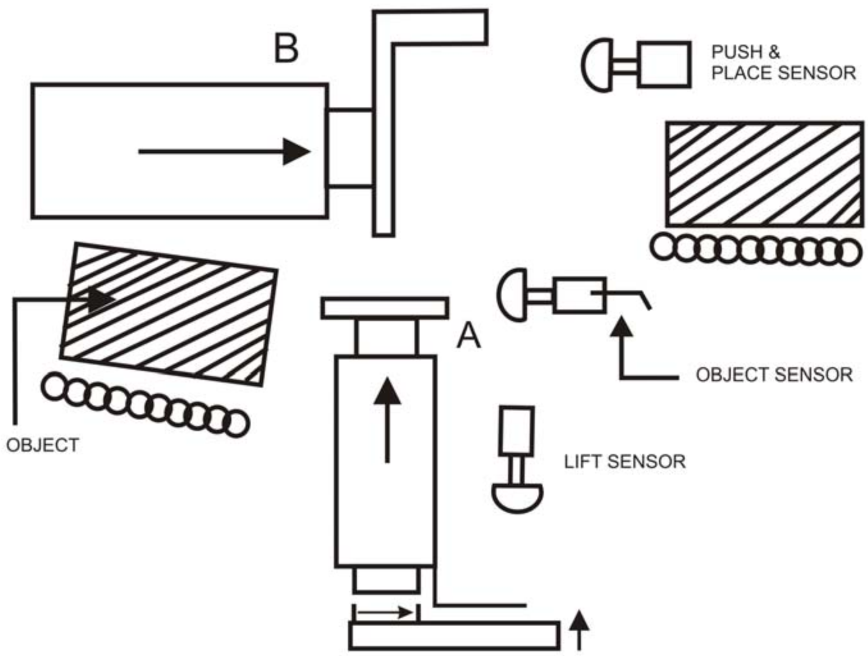


Fig.- 6 : Event based sequence control in an automation system (Schematic view)

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