LECTURE 22 TO 23

PROPORTIAONAL HYDRAULIC VALVES

FREQUENTLY ASKED QUESTIONS

1. Compare electro hydraulic servo valve with proportional hydraulic valves

Servo Valve	Proportional Valve
Close loop control	Open loop control
Very expensive	Less costly compared to servo valves
Low power input (1-3 w)	Require more power (50 W)
High filtration	Moderate filtration
Spool critically lapped	Spools are overlapped
Linear Flow current relation	Nonlinear flow current relations
Very low hysteris 0.1 %	Hysteresis large 0.5 %
Used primarily in closed loop, high performance circuits	Can be used in closed loop control, with moderate performance circuits
Create flow and pressure control	Can be used as flow, pressure , direction control valves

2. Where are proportional valves are preferred

In general proportional valves find most of their applications in open loops situations where pressure and flow are required to change continuously, where multiple fixed flow and pressure valves can be replaced by a single valve and where acceleration and deceleration under control are required.

3. Explain the principle of proportional pressure reducing valve

This operates in a similar manner to a conventional pressure regulating valve, the control spring being replaced by a proportional solenoid. When this solenoid is not energized, the proportional valve is closed unlike the conventional pressure reducing, which is normally open. The output pressure of the valve shown diagrammatically (Figure 17.14), is proportional to the current flowing through the solenoid.

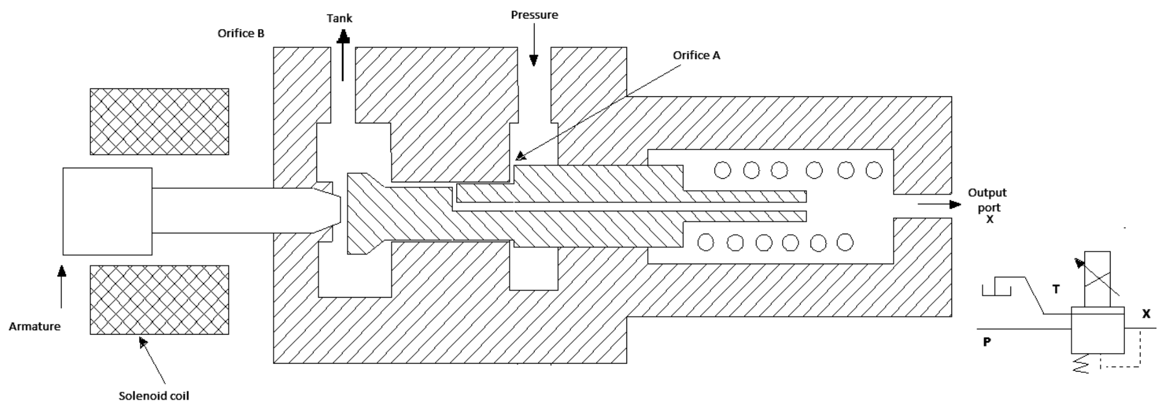


Figure 17.14 Proportional pressure reducing valve

When the solenoid is energized it will move the spool to the right, the control orifice A will open and allow fluid to flow to the output port X. As the aperture of orifice A increases the orifice B's aperture will reduce; the pressure at the control output X is dependent upon the openings of control orifices A and B. This is shown in Figure 17.15

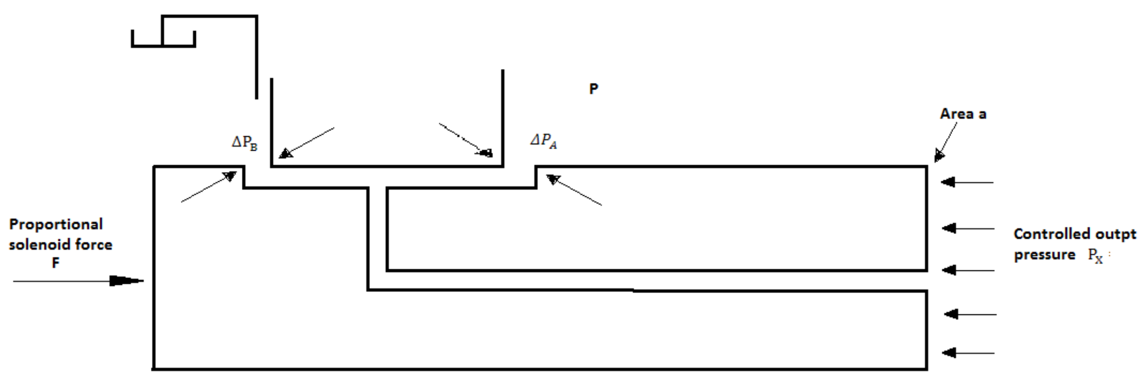


Figure 17.15 Principle of pressure reducing valve

Let the supply pressure be P1. The pressure drops the across the control orifices A and B are P_A and P_B and the output pressure is P_x .

$P_t = \Delta P_A + \Delta P_B$ And $P_X = \Delta P_B$

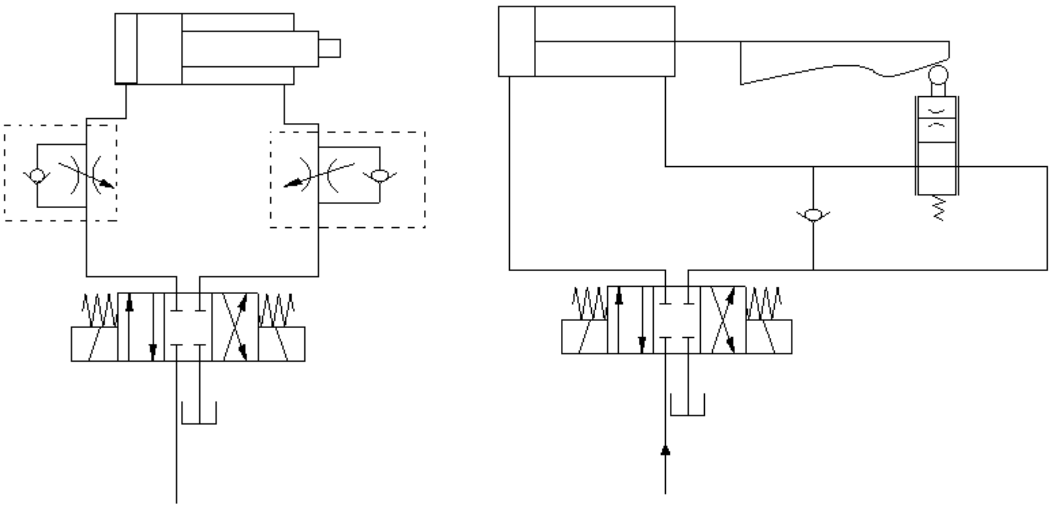
If the control orifice B is fully closed, the $P_x$will equal the supply pressure P_1. The output pressure is applied to the right hand end of the spool and if this is greater than the equivalent pressure exerted by the proportional solenoid, the spool will move to the left. This increases the opening of orifice B and reduces that of orifice A, so reducing the output $P_X a = F$. The output pressure is proportional to the current flowing in the proportional solenoid. There will always be a flow to tank from this type of valve if the output pressure P_X is less than the supply pressure P_1. It is essential that there is no back pressure in the tank line if the valve is to function properly.

4.With the help of neat sketch explain how speed of the cyliners can be controlled using proportional valve

The conventional speed control of a cylinder is by meter in meter out or spill-off flow control valves. This sets a cylinder speed which can be manually varied. Alternatively a cam drive can progressively close or open an adjustable orifice in accordance with a preset speed profile which is altered by changing the cam profile. Examples of these types of circuits are shown in Figure 17.18. The acceleration and retardation of a cylinder can be controlled by:

1. Relief valves limiting then maximum pressure available to accelerate the load.
2. Using a two stage directional control valve with a choke pack to control the speed of movement of the main spool.
3. Using a variable displacement pump.
4. Internal cylinder cushions or external shock absorbers can be used to decelerate the cylinder.
5. Brake valves, deceleration valves and counterbalance valves can be built into the circuit to control the deceleration and sometimes the acceleration of the actuator.

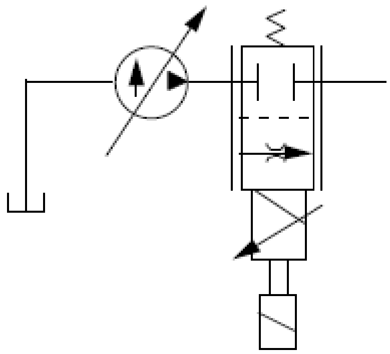
All these manual methods are incapable of continuous variations whilst the system is operating. A proportional control valve in the cylinder circuit enables continuous regulation of speed, acceleration and retardation. If proportional control card is used to drive the valve any adjustments to the maximum current ramp-up and ramp-down have to be carried out by adjusting potentiometers on the card. However a microprocessor or minicomputer may be employed to control the proportional valve by varying the solenoid current over different parts of the cycle.

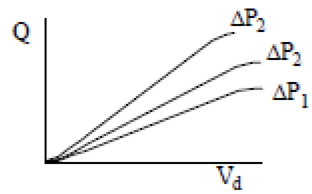


a) Meter out speed control b) cam operated speed control

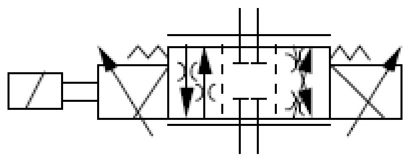
4. Discuss the various control of proportional valves

The simplest application of using a proportional solenoid is that of a throttle valve. Athrottle valves creates a variable orifice in a line. If the upstream pressure is at the deadhead/R.V. setting, then flow through the valve is proportional to the product of the orificearea and the pressure drop across the valve. i.e. $Q = k\ A\ \sqrt{\Delta p}$. For any Δp, wecan change the flow (and hence the velocity of the actuator) by changing the orifice area.Flow is in one direction only and is not controlled (because Δp can change even thoughAo (x) is controlled). A schematic is shown in Figure given below





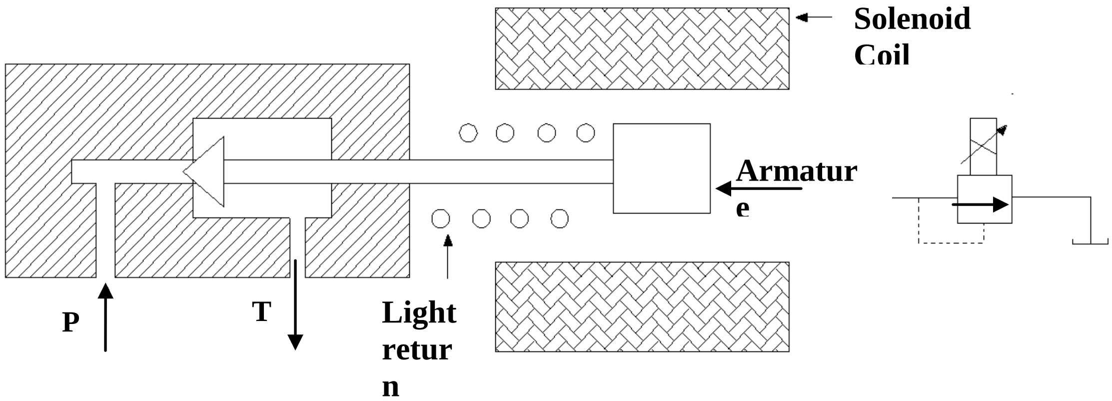
A logical extension to the proportional throttle valve is the directional control valve. A schematic is shown below



The spool has symmetric metering orifices and two proportional solenoids (one for each direction). The amplifiers know which solenoid to activate via the position transducers. The amplifiers are designed to reduce the dead zone to about 5% of full stroke (compared to 15.25% with no compensation). By changing the shape of the metering orifices, it is possible to have different resistances in the various parts

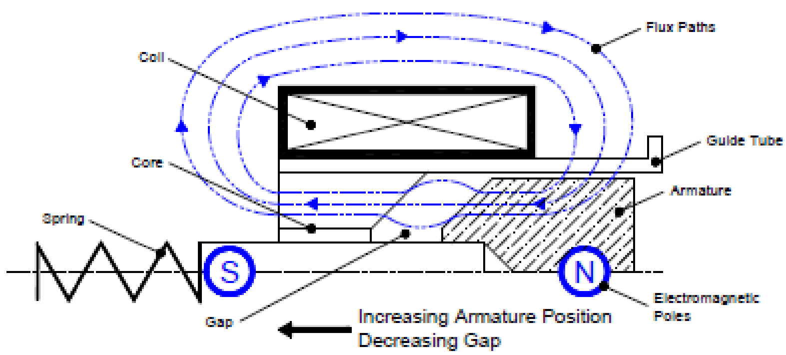
In conventional pressure control valve a spring is used to control the pressure at which the valve operates. The spring is replaced by a DC solenoid in the case of proportional valves; the force set up by the solenoid is controlled by being dependent on the current flowing through it.

Direct acting proportional-relief valves are shown in Figure belowThe proportional solenoid exerts a force on the poppet keeping the valve closed, until the hydraulic pressure at port P overcomes this force and opens the valve. In the design of the relief valve the proportional solenoid acts directly on the valve poppet.

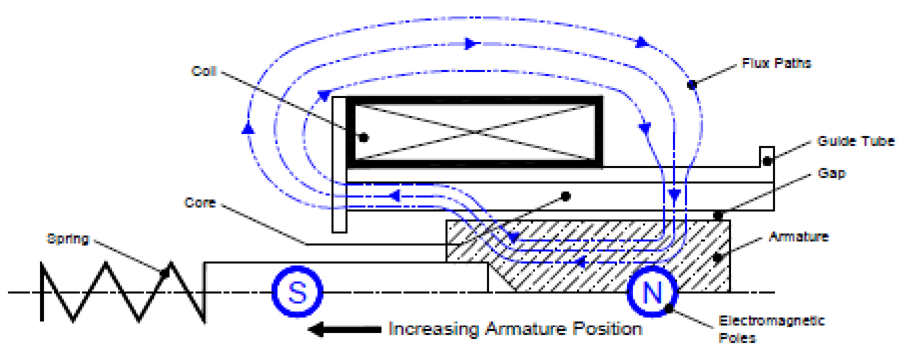


Direct acting proportional relief valve

6. What is the difference between a standard solenoid and a proportional solenoid?



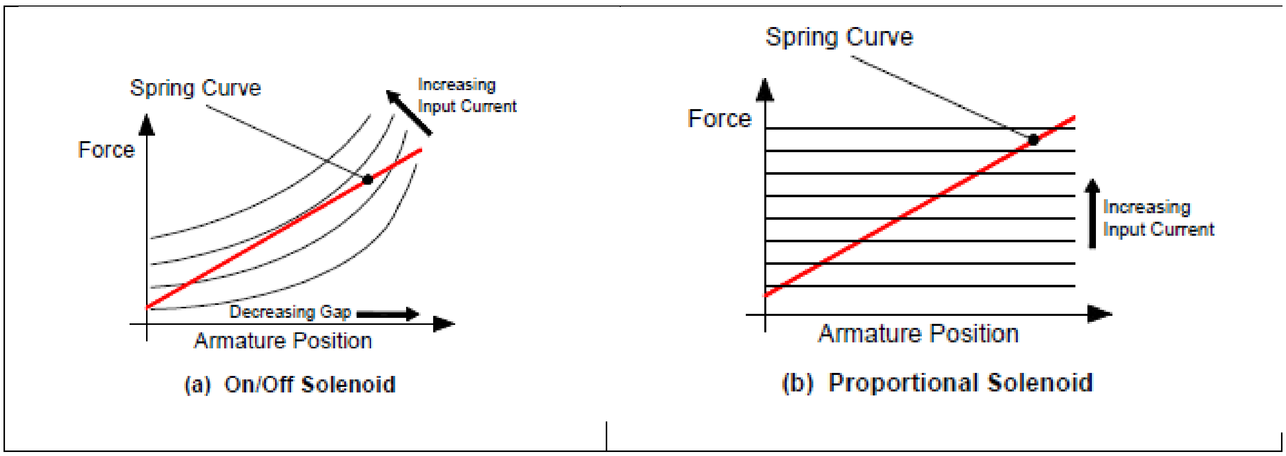
(a) On/Off Solenoid



(b) Proportional Solenoid

For an on/off solenoid the force generated increases as linear gap decreases. By superimposing the return spring curve on this family of solenoid curves it is shown that there are a limited number of intersection points where the spring force and solenoid force would be in equilibrium. On/off solenoids are designed for single current supply systems, where the input current creates a large enough force to exceed the spring force at all positions, moving the spool to its maximum displacement.

With a proportional solenoid the gap is constant throughout the spool stroke. Thus, when the return spring curve is superimposed on the proportional solenoid family of input current curves many intersection (equilibrium) points are found. By utilizing a variable current supply to change the input current many spool positions can be created; thus spool position is proportional to input current.



(a) On/Off Solenoid (b) Proportional Solenoid

7. Explain the concept of operation of a proportional solenoid

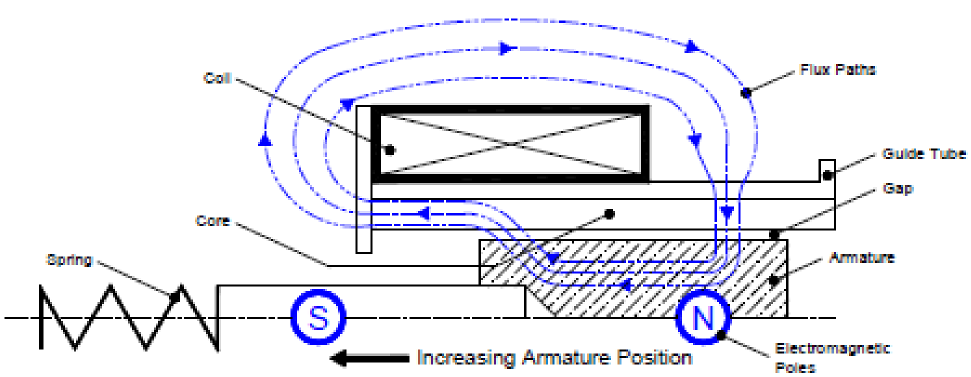


Figure 1 : Proportional Solenoid

Solenoids are electro-mechanical interface devices that convert electrical input into an applied force On/off type electro-hydraulic valves use a solenoid to move the valve spool from one position (off or no flow) to another position (on or maximum flow). A mechanical spring opposes spool movement and returns the spool to the opposite position once electrical power has been removed from the solenoid. This operation can be classified as *digital* since the flow paths can be in only one of two states. On the other hand, proportional type electro-hydraulic solenoid valves can position the spool at an infinite number of locations between the start and end positions. The mechanical spring employed in this application provides both the means for proportionality and again returns the spool to the start position when no electrical power is supplied. Consequently, proportional solenoid valves can be classified as *analog* devices which provide more functionality and opportunities within the field of electro-hydraulics.

The key difference between on/off and proportional solenoids is the shape and orientation of the core and armature to create a *constant gap device*. A proportional solenoid is constructed such that the gap is perpendicular to the direction of armature movement and therefore independent of armature position

Both on/off and proportional solenoids have the same basic construction; a wire coil surrounds a ferromagnetic core with a paramagnetic guide tube (Figure 2)

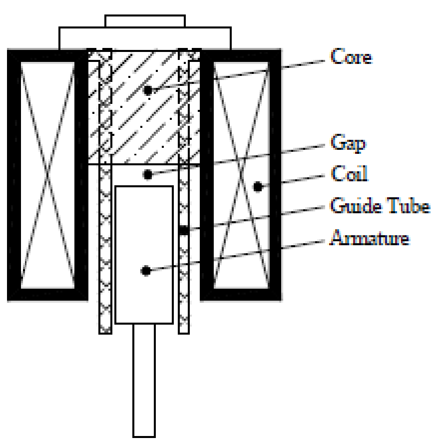


Figure 2 : construction of solenoid

When an electric current is supplied to the coil a magnetic field that intersects the core and armature is established. The coil creates two magnetic poles at the opposite ends of its length, where the flux paths circulate. These magnetic flux paths generate a linear force attempting to center the armature within the coil length (between the electromagnetic poles). An on/off solenoid’s magnetic force increases as the gap between the core and armature decreases (classified as a variable gap device) because the reluctance of the magnetic flux circuit is decreased. The key difference between on/off and proportional solenoids is the shape and orientation of the core and armature to create a constant gap device. A proportional solenoid is constructed such that the gap is perpendicular to the direction of armature movement and therefore independent of armature position (Figure 1). Thus, for a given current through the coil a constant force over the working range of armature movement (spool stroke) is created. Examining the equation for force generated by either an on/off or proportional solenoid can show this principle:

8. What is the purpose of dither in a proportional circuit

The dither adjustment allows the system to be trimmed so that the valve spool moves with higher dither frequency but at such a low amplitude that the load does not respond to it. This reduces the valve dead band with no detrimental effect on the load.

9. Explain the difference between force control and position control in proportional control valves.

In force control Proportional valves, force is controlled electrically and by applying the force to a compression spring its deflection can be controlled. If the spool is acted on by a spring at one end and a proportional solenoid on the other the orifice size can be varied along with the control current.

In order to increase the accuracy and extend the range of applications of proportional control valves, a linear transducer may be fitted to measure the spool position. The output from the transducer is a voltage which is proportional to the spool displacement and is continuously varying through the total spool movement.

When a conventional solenoid is energized, the plunger travels its full stroke. A given force is developed at the moment actuation occurs. With a force controlled proportional valve , a provision is made to increase the force output by the solenoid proportional to the input signal. With a stroke controlled valve , the stroke distance is proportional to the input signal. Both types of solenoid provide an opening of the valve proportional to the magnitude of milliamp current applied to the valve. Spool movement is proportional to the input current.