**Oil Hydraulics and Pneumatics**
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**Proportional Valve Technology**
**Lecture - 88**
**Part 3: Conventional solenoids and Proportional solenoids, Open-loop and Closed-loop system, Proportional valve vs. Servovalve, Concluding remarks**

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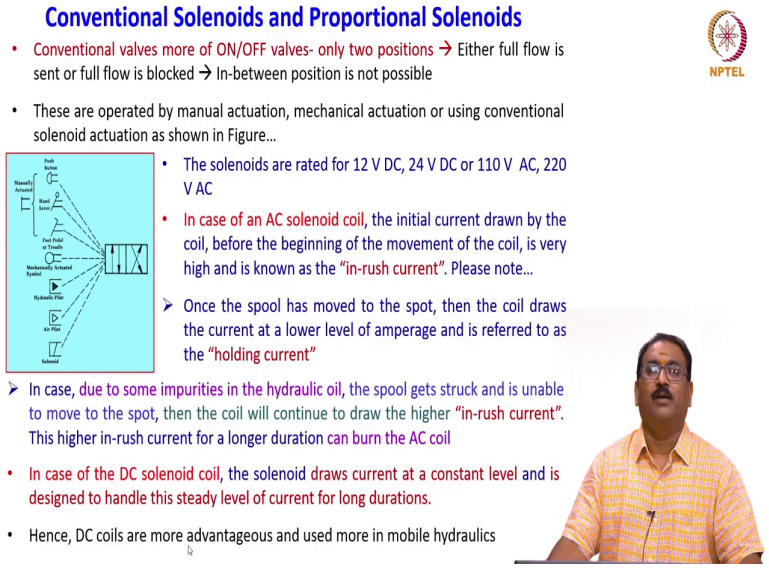


My name is Somashekhar, course faculty for this course. Conventional solenoids and a Proportional solenoid, what is this? As I have told you conventional valves use a conventional solenoids meaning ON-OFF valves, but in case of the proportional valves we are using the proportional solenoids, what are these? Conventional valves more of ON OFF valves, only two positions, either full flow is sent or full flow is blocked. In between position is not possible as I have told you in the previous slide.

These are operated by manual actuation mechanical actuation or using the conventional solenoids as shown in the figure here. Here I have shown you 4 by 2 way valve; valve will be in the left position or a right position left position is a parallel configuration, right one is a crossed configuration. This may be achieved by using any type of actuation either a manual actuation or a mechanical actuation or a solenoid actuations.

What for it is? To moving the spool either to the left or to the right, to send the flow in the parallel configuration or a crossed configurations to move the piston and cylinder in the linear actuator either left to the right or right to the left. Similarly, in the rotary actuator rotating in the clockwise direction or anti-clockwise directions.

The solenoids are rated for 12 volt DC, 24 volt DC or a 110 volt AC or 220 volt AC. What is this? In case of AC solenoid coil, the initial current drawn by the coil, before the beginning of the movement of the coil is very high and is known as the in-rush current.

Please note, once the spool has moved to the spot, then the coil draws the current at a lower level of amperage and is referred to as the holding current. In case, due to some impurities in the hydraulic oil, the spool gets struck and is unable to move to the required spot, then the coil will continue to draw the higher in-rush current. This higher in-rush current for a longer duration can burn the AC coil.

In case of the DC solenoid coil, the solenoid draws current at a constant level and is designed to handle this steady level of current for long durations. Hence, DC coils are more advantageous and used more in mobile hydraulics.

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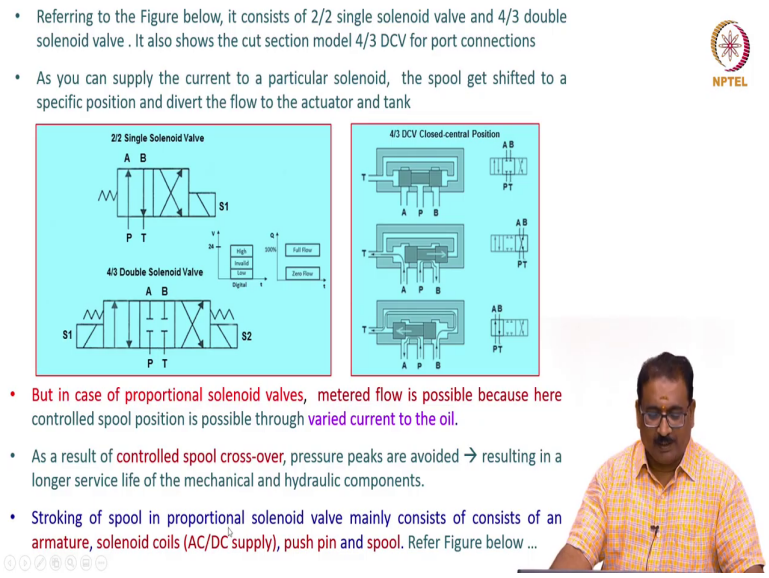


Referring to the figure below, it consists of 2 by 2 single solenoid and 4 by 3 double solenoid conventional valve what I am showing you here. It also shows the cut section model of the 4 by 3 for port connections. How it is? Now, we will see friends, here, this is a 4 by 2 valve. The middle position is a parallel. P is connecting to A, B is connecting to T when the solenoid is actuated, it will shift to the crossed configurations.

When it is de-energized, what happen? It will go to the null position; null position is this P is connecting to 2, B is connecting to 2. It is the single solenoid. Now, we will see down here 4 by 3, three positions are there you will see; middle one is a null position is achieved through the spring at the spool where all ports are blocked. Then left side solenoid is there S 1, right side solenoid is S 2.

When you will energize the S 1 it will shift to the parallel configuration to send the flow or when you will energize the right solenoid it will jump to the crossed configuration to send the flow all are ON – OFF valve remember. But, you will see here when you are using the digital meaning it is the conventional valves will work with the low; low means no current to the solenoid that time it is in the null positions.

When you will give the current input digital what it will? It will jump to the high meaning 24 volt. What happens here? The full flow. When there is no voltage input, the zero flow; zero flow means if it is in the 4 by 3 double solenoid what I am showing you. This figure is for this. When you will give the 24 volt, full flow is going to the actuator.

This is the way you know same thing what I have shown you here the null position here A is blocked, B is blocked, P is blocked, T is blocked through the stiff springs. This is a 4 by 3 closed central neutral. Here you crossed configuration you will see A is connecting to T, P is connecting to B this is the spool. This spool is moved either to the left or a right through the solenoid S 1 and S 2, very simple it is.

As we can supply the current to a particular solenoid the spool get shifted to specific position and divert the flow to the actuator and the tank, but in case of proportional solenoid valves metered flow is possible because here the controlled spool position is possible through the varied current to the coil.

As a result of controlled spool crossover pressure peaks are avoided which are prone to occur in the conventional solenoid, here no; resulting in a longer service life of the mechanical and hydraulic components. Stroking of spool in proportional solenoid valve mainly consists of an armature, solenoid coils, push pin and spool.

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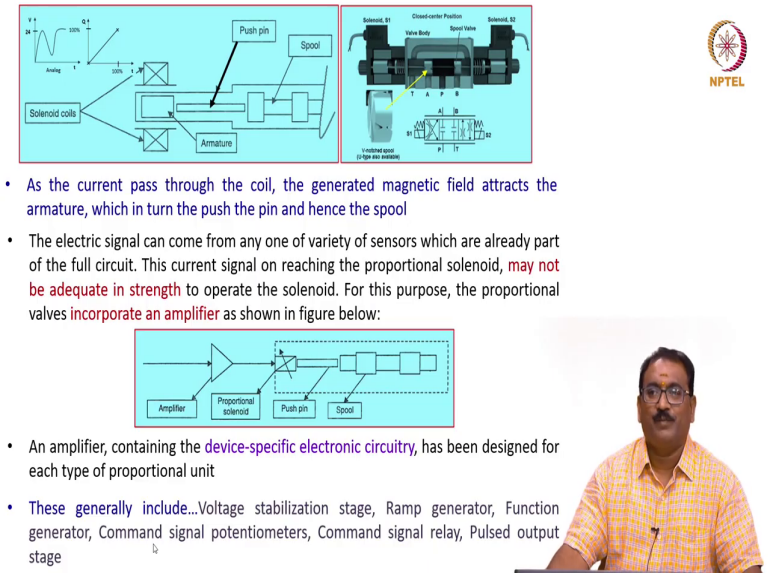


This will show the schematic diagram of proportional solenoid which consist of the armature, the coils, push pin and a spool and here you will see this friends on either side the solenoid S 1 and a solenoid S 2 here you will see the spool is having the V notched spools spool design here a V notched shape or it is also a U shaped to ensure the required flow to the actuator based on the customer requirements.

Please take care here friends the symbolic representation of the 4 by 3 proportional valve. You will see here you have to draw the two horizontal line over here which will show you the solenoids when you are giving the different current it will move the spool to the required level, then it will give the metered flow. You will see here how they are marked on the left position as well as in the right position. This is the symbolic representation of the proportional valves.

As the current pass through the coil, the generated magnetic field attracts the armature, which in turn the push pin and hence the spool. The electrical signal can come from any one of variety of sensors which are already part of the full circuit. This current signal on reaching the proportional solenoid may not be adequate in strength to operate the solenoid.

For this purpose, the proportional valves incorporate an amplifier as shown in the figure below. Here you will see friends here, then also you will see here friends on the solenoid you have to mark the arrow mark. You will see here on the solenoid you will mark it arrow mark over it, meaning here the solenoid is proportional one it is based on the current input it proportionately move the spool valve, ok. Here it is amplifier to give the strengths to the signal what it is coming to the solenoid.

Now, also you will see friends here in this figure I have shown you the analog input; previously conventional valve it is digital. Digital means either low or a high; in between it is not possible. But, you are will see here the 24 volt how signal is varying analog signal, which will results in when there is no current no flow.

When you supply the full current for example, 100 percent voltage if you will give, what happen? The flow will get linearly; slowly it will go based on the current input. See the characteristics curve for the flow versus time also the voltage input versus T to the solenoid coil.

An amplifier, containing the device specific electronic circuitry, has been designed for each type of proportional unit. These generally include voltage stabilization stage, ramp generator, function generator, command signal potentiometer, command signal relay, pulsed output stage. But, due to the limitation I am not touching any of the electronic circuitry to drive the spool valves.

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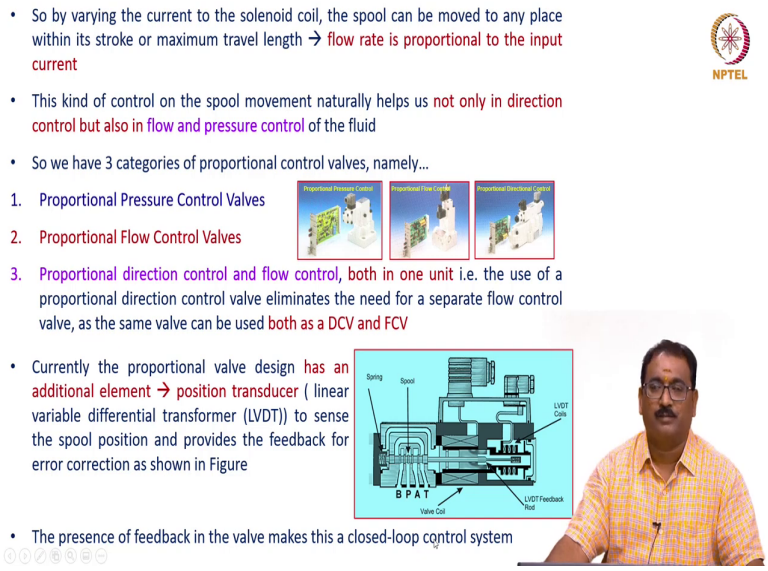


So, by varying the current to the solenoid coil, the spool can be moved to any position within its stroke or a maximum travel length. Flow rate is proportional to the input current. This kind of control on the spool movement naturally helps us not only in the direction control, but also in flow and pressure control of the fluid.

So, we have 3 categories of proportional control valves available commercially, namely; proportional pressure control valves, proportional flow control valves, proportional directional control and a flow control, both in one unit that is the use of proportional directional valve eliminates the need for a separate flow control valve, as the same valve can be used as a direction control valve and a flow control valve.

Now, the here the picture will show you the proportional pressure control valve along with the electronic circuitry, proportional flow control valve along with the electronic circuitry, proportional direction control valve with the electronic circuitry.

Currently the proportional valve design has an additional element; position transducer which is generally linear variable differential transformer LVDT to sense the spool position and provides the feedback for the error correction as shown in the figure below.

Here you will see friends, here again it is a spool valve. Here the spring one side and other side is a, what is this? Solenoid, one side is the spring and null position to maintain the valve positions and other side is a solenoid. And, solenoid position is monitored using the LVDT. See here LVDT is there, it will measure the position of the solenoid when it will move and this will be given as an error signal to the electronic circuitry until it will reaches the required position.

The presence of feedback in the valve makes this a closed-loop control system.

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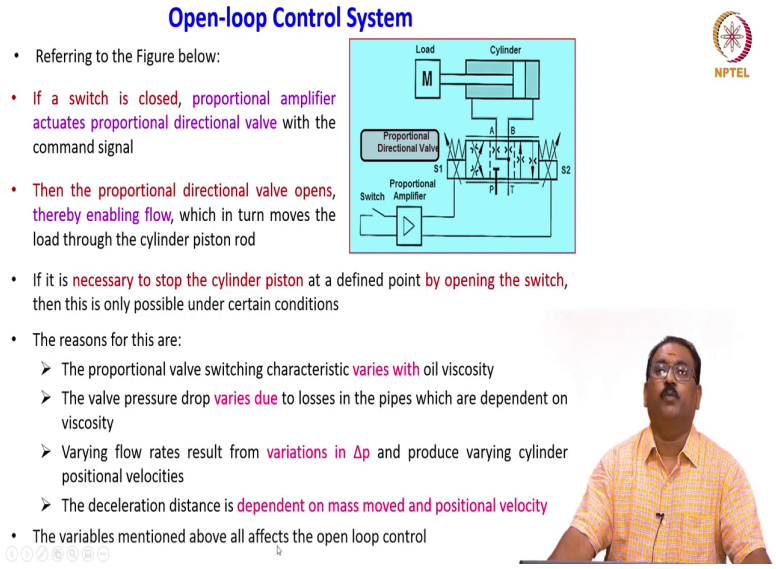


Quickly I will show you open-loop control system. Generally, as I have told you when the proportional valves are arrived in the market they will treated as a open-loop control even though electronics is embedded to vary the spool positions. Referring to this figure here I am showing you here a cylinder and load.

See here friends it is a 4 by 3 direction control proportional valve it is, here proportional amplifier based on when the switch is on based on the current input to the coil proportionality it will move the spool once it is actuated S 1 or a S 2, correct? If a switch is closed, what happen? The proportional amplifier actuates the proportional direction valve with the command signal.

Then the proportional directional valve opens, thereby enabling a flow, which in turn moves the load through the cylinder piston rod. If it is necessary to stop the cylinder piston at the defined point by opening the switch then this is only possible under certain conditions.

The reason for this are – the proportional valve switching characteristics varies with oil viscosity. The valve pressure drop varies due to losses in the pipes which are dependent on the viscosity. Varying flow rates results from variations in delta p and produces a varying cylinder positional velocity. The deceleration distance is dependent on mass moved and a positional velocity. All are related terms friends, see here.

The variables mentioned above all affects the open loop control. Here there is no feedback from the actuator to the proportional amplifier, only whatever the current you will give proportionately it will switch and the metered flow will go to the actuator, then load will be moved from the left to right or right to left based on the current input. But, no guarantee whether it is moved or not because of the many reasons here.

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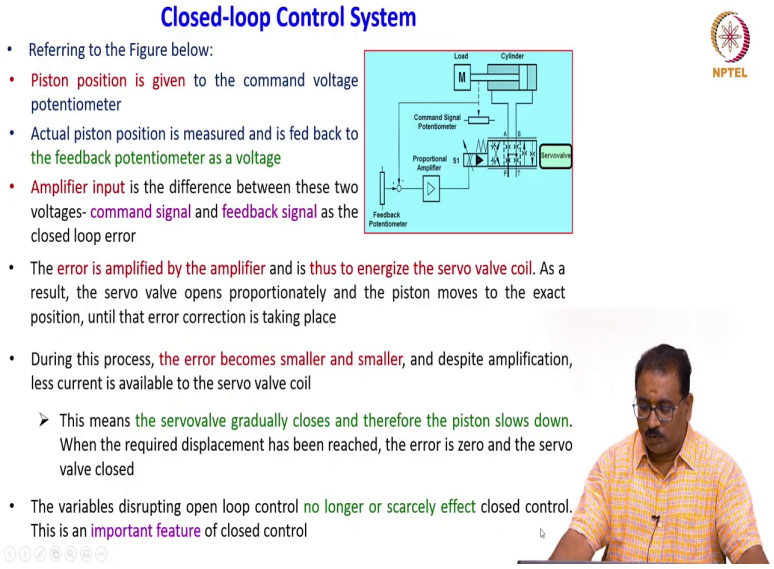


Closed-loop control system: Referring to the figure below here, here as usual it is same previous sketch, but here the many things are there here. See here the piston position is captured and putting to the feedback. See here friends, how it is? The piston position is given to the command voltage potentiometer. Actual piston position is measured and is fed back to the feedback potentiometer as a voltage.

Amplifier input is amplifier input is the difference between the two voltages that is the command signal as well as the feedback signal as the closed loop error. The error is amplified by the amplifier and thus to energize the servo valve coil. As a result, the servo valve opens proportionately and the piston moves to the exact position until that error correction is taking place to zero.

During this process the error becomes smaller and smaller and despite amplification less current is available to the servo valve coil. This means the servo valve gradually closes and therefore, the piston slows down. When the required displacement has been reached the error is zero and the servo valve closed.

The variables disrupting open loop control no longer or scarcely effect a closed control. This is an important feature of closed loop control system.

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Now, quickly we will see friends the proportional valve versus servovalve. I will give you typical performance characteristics.

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| Sl. No. | Parameters | Proportional Valves | Servovalves |
|---|---|---|---|
| 1 | System | Open-loop system | Closed-loop system |
| 2 | Feedback | No | Yes |
| 3 | Electrical Operator | Proportional solenoid | Torque motor |
| 4 | Manufacturing Precision (Comp. to conventional solenoids) | Moderately high | Extremely high |
| 5 | Valve Lap | Overlap spool valve-dead zone on either side of the null position | Critical lap or underlap spool valve- no dead zone |
| 6 | Spool Center (dead-band) | 10 % to 30% | Nil |
| 7 | Response time for the valve spool to move fully over | 40 ms to 60 ms | 5 ms-10 ms |
| 8 | Response (frequency at 29.3% flow reduction) | 2 Hz to 10 Hz | 10 Hz to 300 Hz |
| 9 | Hysteresis | Without armature feedback→ Approx. 5% With armature feedback → Approx. 1% | Approx. 0.1 % |
| 10 | Repeatability/threshold | Up to 10% | Less than 3% |
| 11 | Contamination sensitivity | Moderate | High |
| 12 | Filtration requirements | 10 microns | 3 microns |
| 13 | Cost (Comp. to conventional solenoids) | Moderately expensive | Very expensive |

Serial number, parameters, proportional valves and a servovalve; typical characteristics. System we will see generally as I have told you proportional valves are open-loop systems. Currently, they made the closed-loop by measuring the output cylinder output and giving the feedback, but servovalves are always a closed-loop system. Feedback; no feedback because it is open loop as I have told you when it is developed. Closed-loop; because feedback is there, yes.

Electrical operator – proportional solenoid here, it is a torque motor is in general. Manufacturing precision – compared to the conventional solenoid, moderately high it is, here extremely high. Valve lap you will see here overlap spool valve-dead zone on either side of the null position. Here critically lapped or a underlap spool valve – no dead zone. Spool center a meaning it is a dead-band what an 10 percent to 30 percent; here it is nil.

Response time for the valve spool to move fully over – 40 millisecond to 60 millisecond; here 5 millisecond to 10 milliseconds. Response meaning a frequency at 29.3 percent flow reduction, proportional is 2 hertz to 10 hertz, but you will see here 10 hertz to 300 hertz. Hysteresis you will see – without armature feedback approximately 5 percent, with armature feedback approximately 1 percent; here approximately 0.1 percent.

Similarly, other characteristics like a repeatability and threshold you will see up to 10 percent in proportional, here less than 3 percent in servo valves. Contamination sensitivity you will see it is a moderate and it is very high. Filtration requirement you will see, 10 microns here a 3 micron. Cost again compared to conventional solenoids moderately expensive it is proportional and it is very expensive as compared to proportional valves.

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Concluding remarks: so, in today's lecture we have discussed in detail the followings. Status and developments in fluid power system, integration of electronics in fluid power circuits, different levels of controls in various applications like a industry and a defense applications, important features of proportional and servovalves.

Valve configurations and characteristic curves, quick glance on flapper valve and a jet pipe valve, status on proportional valve technology, proportional valves an introduction, signal sequence in proportional control valves, possible functions and a proportional valves, conventional solenoids and a proportional solenoids, open-loop and a closed-loop systems, finally; the proportional valve versus a servovalves.

Ok friends, we will stop now. See you all in the next class, until then bye bye. Thank you one and all for your kind attention. [FL].