# Oil Hydraulics and Pneumatics

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## Electro Hydraulic Servo Valve (EHSV)
## Lecture - 90
## Part 2: Servovalve constructions- Different stages, Flapper-nozzle electrohydraulic servovalve- constructions and operations, Electromagnetic motors, Electromagnetic torque motor

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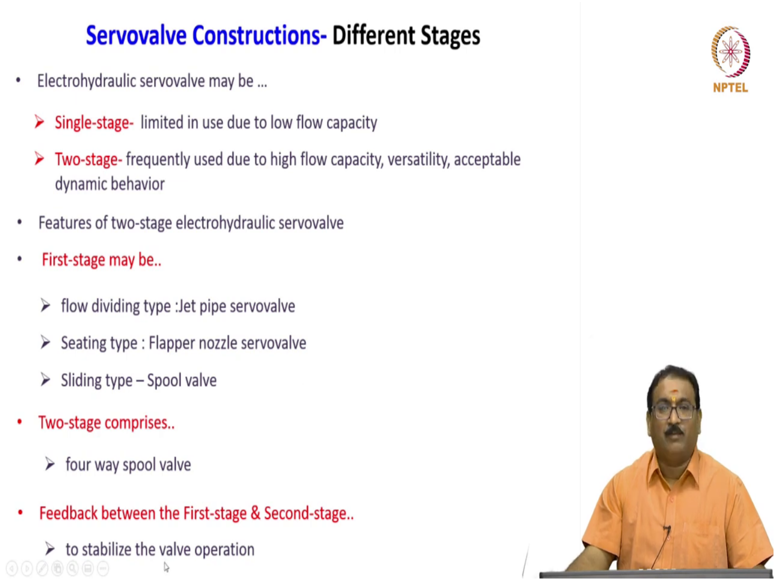


My name is Somashekhar course faculty for this course. Let us we will see the Servovalve construction. Here, I am showing you the different stages starting with single stage, two-stage, three-stage, many variants are there in the servovalves, let us we will see now. Electrohydraulic servovalve may be the single stage, limited in use due to low flow capacity.

Two-stage frequently used due to high flow capacity, versatility, acceptable dynamic behavior.

Here, the features in the two-stage valves, first-stage may be the flow dividing type: Jet pipe servovalve or the seating type: Flapper nozzle valve or a sliding spool valve. Second stage generally comprises of four-way spool valve. Our objective is to control this four-way spool valve precisely to meter the flow to the actuator.

Then, in between the first and second stage, there is a feedback element to stabilize the valve operation. What is this? Applied torque on the armature is balanced by the restoring torque from the spool movement, this is a to stabilize the valve operation as I have told you.

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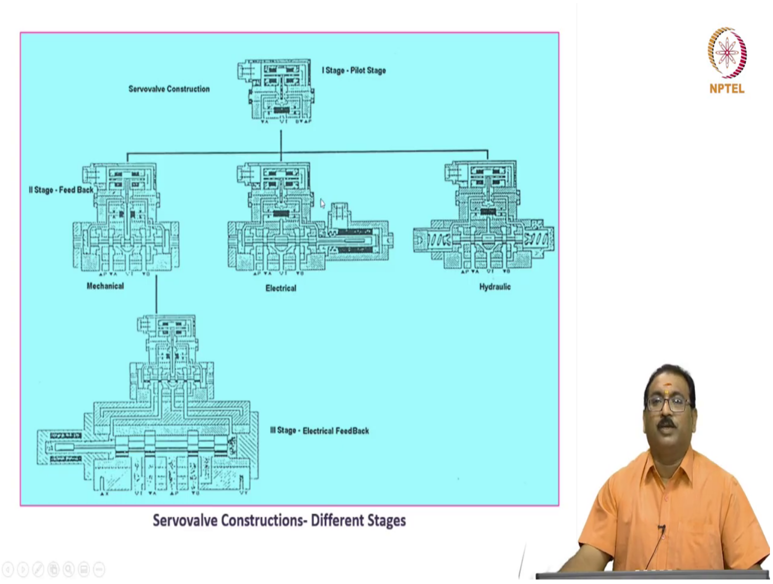

Let us quickly I will show you here the schematic diagram in which the first-stage pilot valve first stage it is directly flapper is moved here and here. You will see here the second stage.

The feedback may be the mechanical feedback to the first-stage or a electrical feedback to the first-stage or a hydraulic feedback to the first-stage. Also based on the requirement, the third stage is also available. Here, I am showing you the electrical feedback to here and then here. What are this first stage, second stage? I will explain to you in the next slide, no need to worry.

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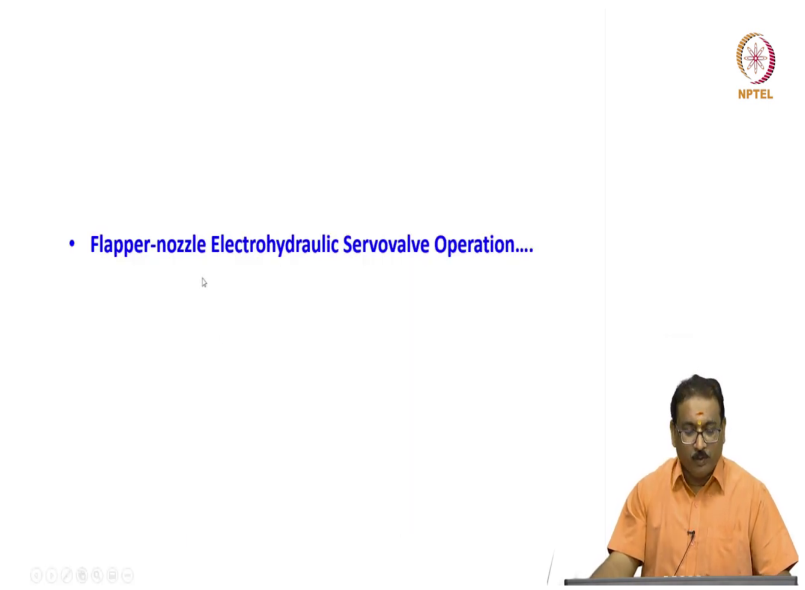


Now, I will show you the flapper-nozzle electrohydraulic servovalve operation.

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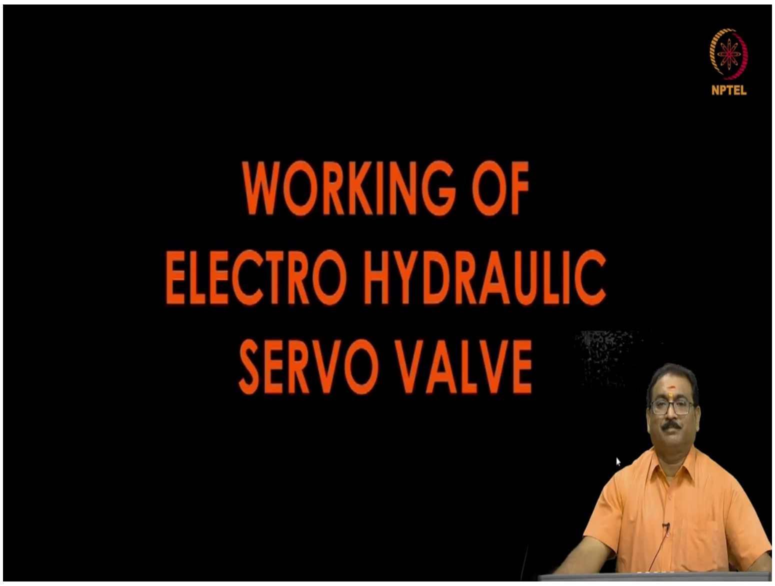

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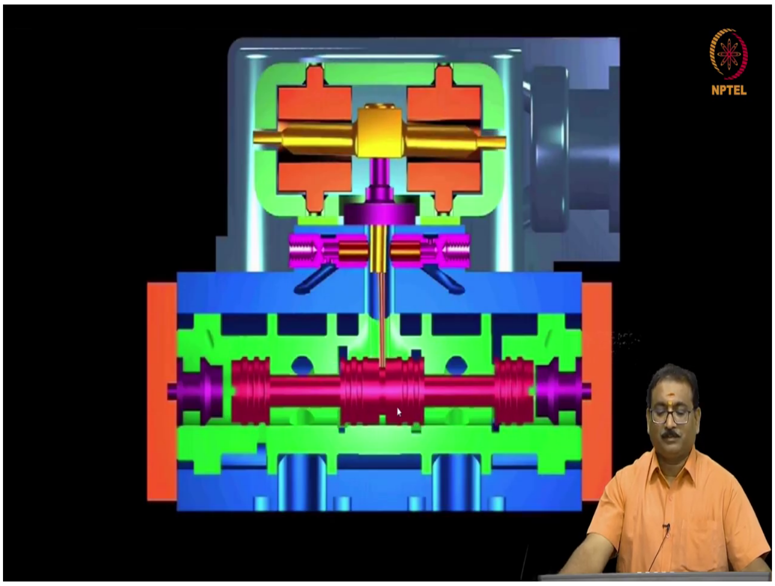


Torque motor second stage spool valve.

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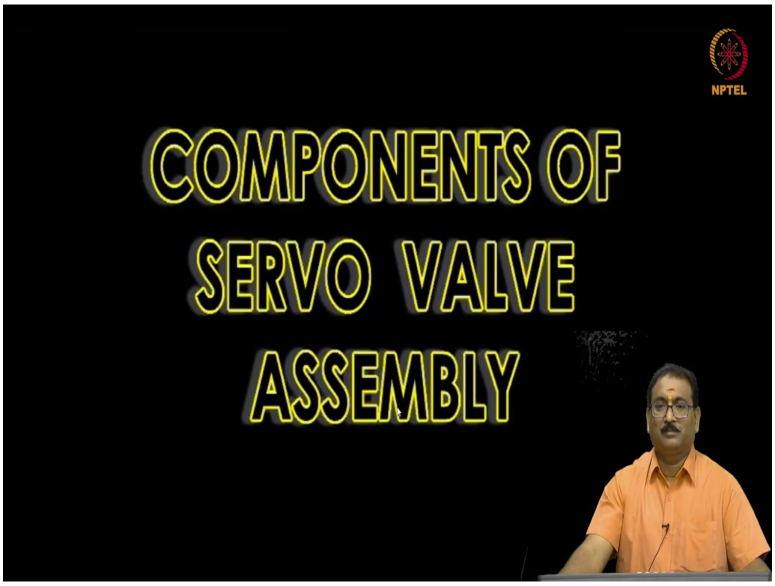


So, many components are there.

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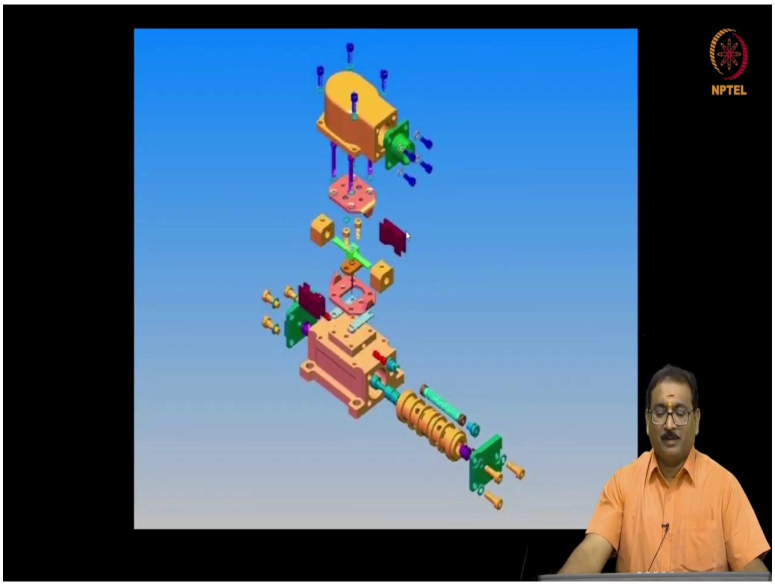


Just you will see here, exploded view and now, it is assembling. This is a spool valve, spool you know sleeve and end plates, this is the valve body, here torque motor top. Torque motor is manufactured separately, valve body is manufactured separately, then they are assembling. You will see here the complete valve is very small.

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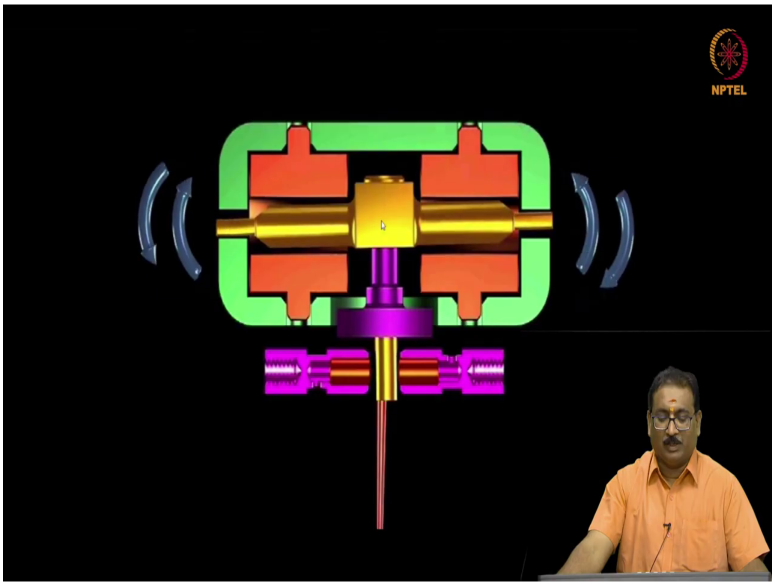

Now, we will see the torque. This armature 4 air gaps are there. You will see how the torque is applied on the armature.

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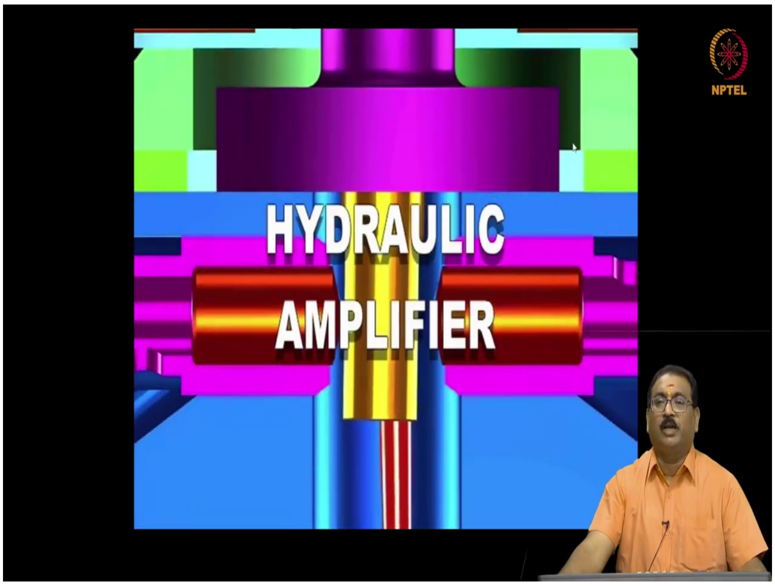


These are the pole pieces and permanent magnet; I will explain to you later, no need to worry.

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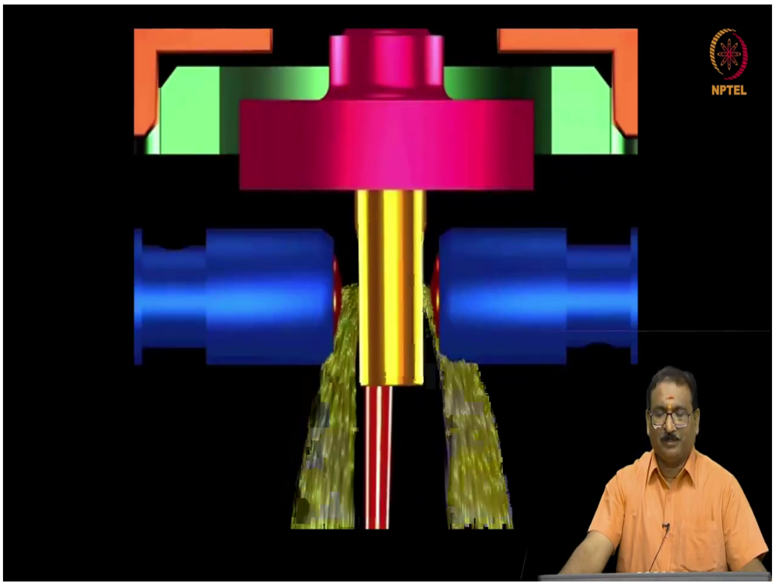

Flow, this is a flapper.

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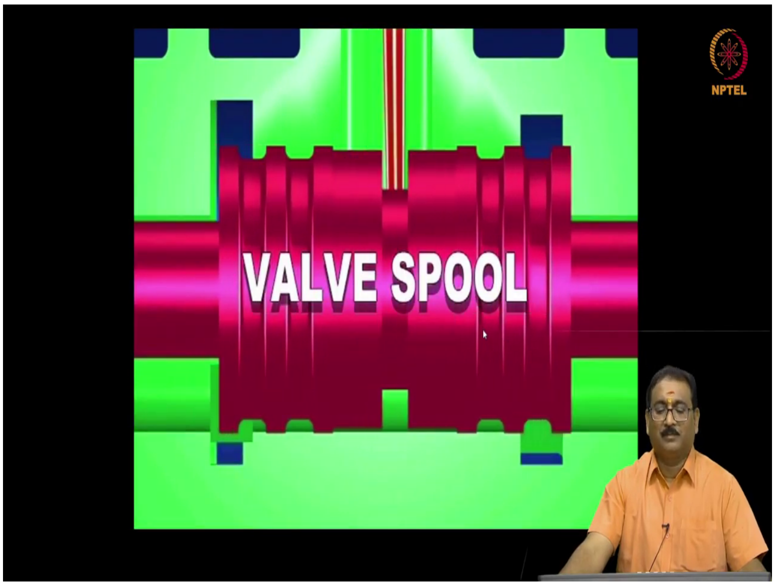


This feedback spring, spool valve.

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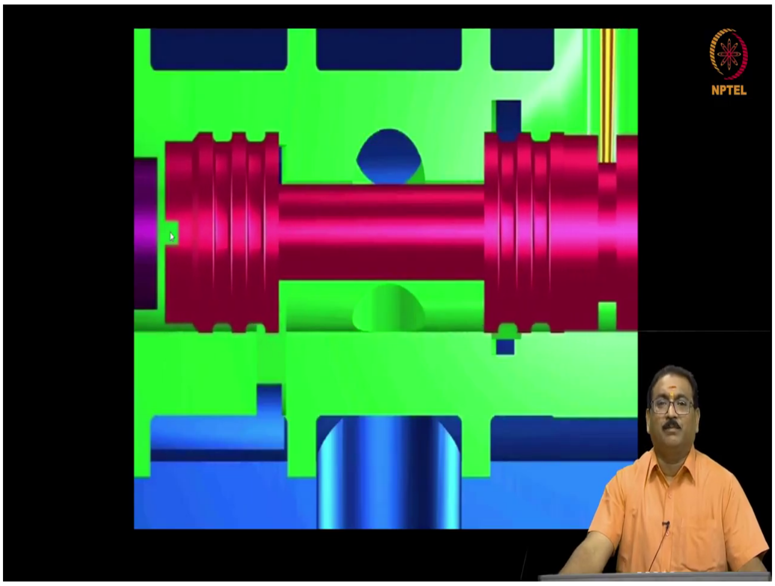

You will see the movement, a very very small less than 1 mm.

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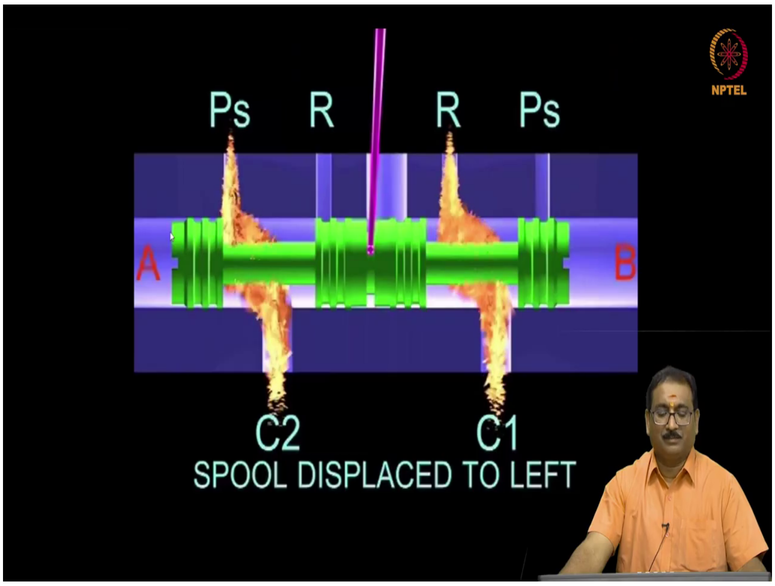

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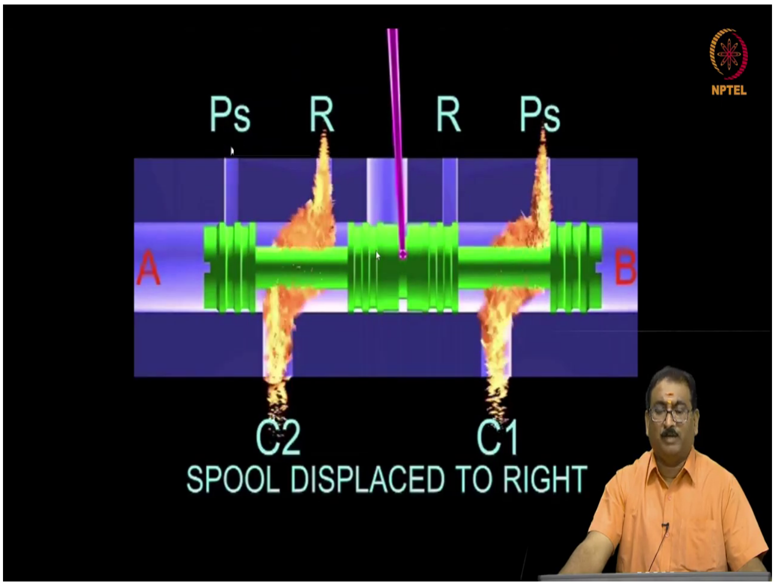


You see the connection of the push when the spool valve will move in the different positions due to pressure differential.

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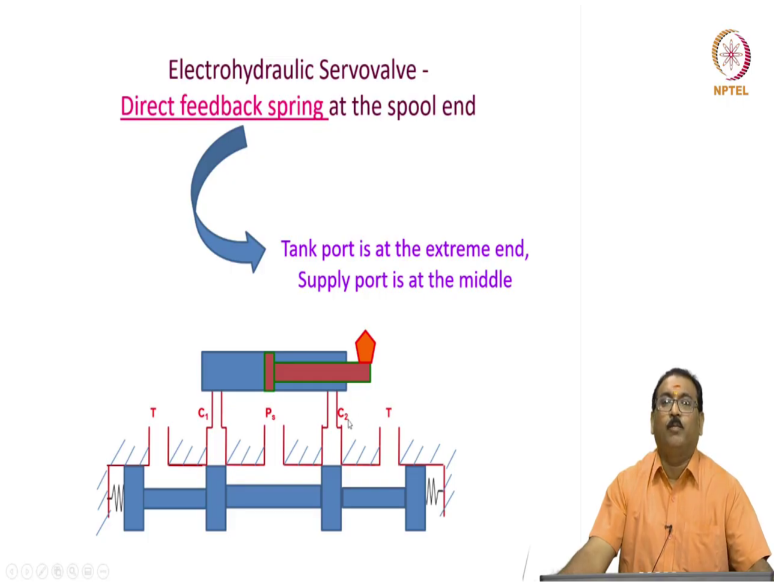


Now, we will see the electrohydraulic servovalve uses the direct feedback spring at the spool end. Meaning you will see here the different configurations are there, port configuration what you can call it as. Here, tank port is at the extreme end, supply port is at the middle. I will show you how it is connections. This is a spool valve, here you will see the pressure port is at the middle, tank ports are the extreme end.

Here, C 1 and C 2 are the control ports, or the actuator port connected here, correct here. In the middle position, the ports are blocked, in case of null cut valve or a zero-lap valve. What is a zero-lap valve? The port width is equal to the width of the spool valve and we will see here, the step springs are there on either side of the spool valve.

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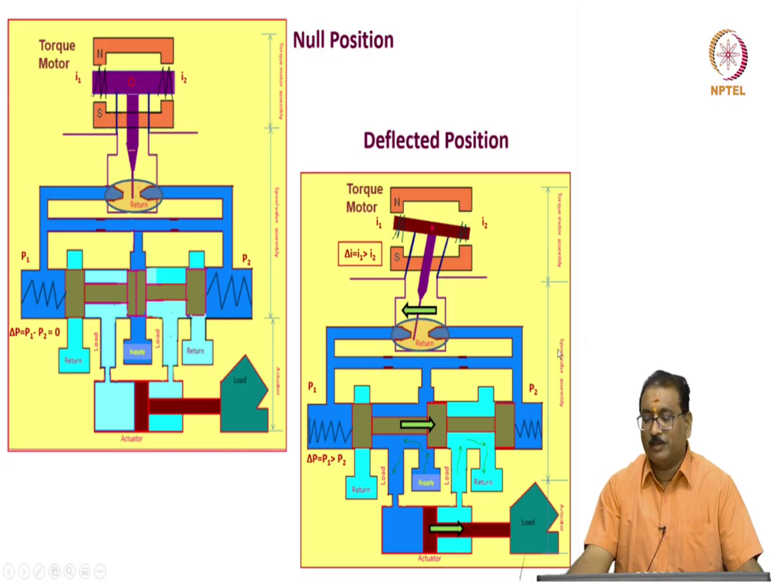


Now, we will see in the null position, this is a torque motor correct and it is a spool valve. Torque motor consist of north pole piece, south pole piece, armature mounted on the fractural tube, pivoted here and carries the your flapper, this is the flapper, these are the two nozzles. You are seen in animation, continuously flow is coming at this. In null position, large amount of flow is going to the tank.

Then, when you will deflect armature, intern the flapper. You will see here, I am deflected. How I am deflecting this torque motor? By applying the differential pressure i 1 and i 2 in the torque motor coils. When i 1 is greater than i 2, it will deflect here. When i 1 is less than i 2, it will deflect in the other side. When it will deflect this side, what happens here? The pressure starts building here.

P 1 is greater than P 2 across the spool valve, then it will starts moving. When it will starts moving, what happens friends here? Supplies is at the middle, it will go to the load, then whatever the flow is there, it will go to the return line, correct. Torque motor stage, spool valve and then, actuator.

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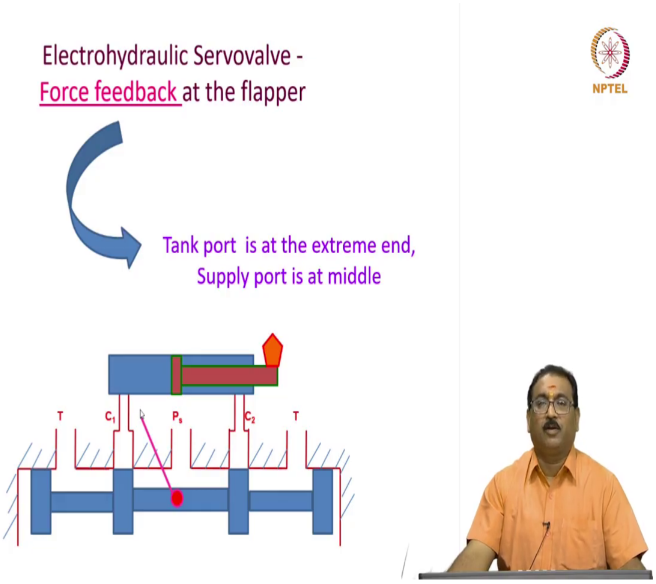


Now, I will show you one more configuration, here it is the force feedback, previously you are seeing the stiff spring across the spool valve. Now, we will see here, now the force feedback at the flapper.

Again, I am using the tank port is at the extreme end, supply port is at the middle. You will see here friends, pressure port middle, tank port extreme. Now, we will see this movement, spool movement due to the P 1 and P 2, pushes the feedback spring to bring back the flapper to the null positions always for the given torque.

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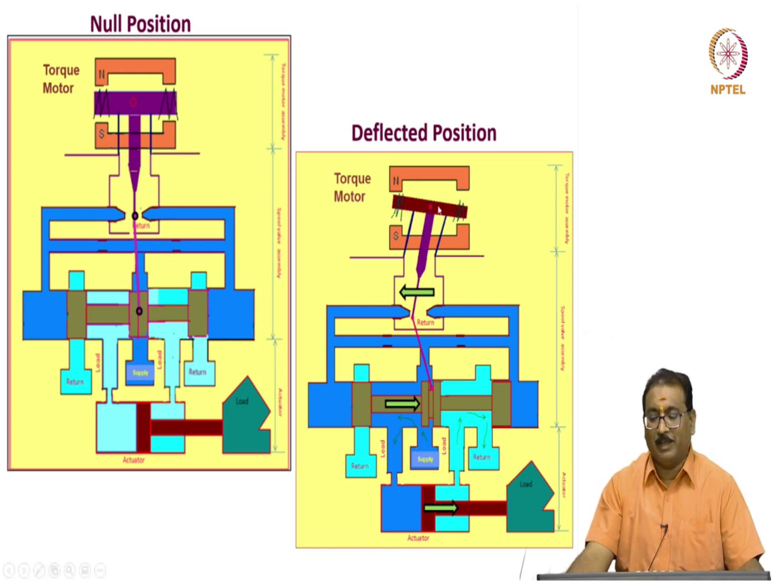


Now, I will explain to you in the figure here. Here, it is a null position, the flapper is at the middle, spool is at the null positions, no flow is going. When you will apply the torque, torque you apply how it is? By passing the current i 1 and i 2, then it will rotate, the torque will generate, correct force multiplied by the distance it will move.

Then, what happens here? You will see here, it will close, then what happens pressure P 1 is greater than P 2, the spool starts moving. During this movement, you will see here the feedback spring is rigidly connected to the end of the flapper. This movement will bring backs the flapper to the null position whatever the input you are given here.

Meaning the applied torque at the torque motor is balanced from the restoring torque to bring back to the null position by the movement of this spool. For any current input, it will deflect, and pressure will starts building on either side, spool will move to bring back the flapper to the null position through this feedback spring. This is what is known as a steady state response.

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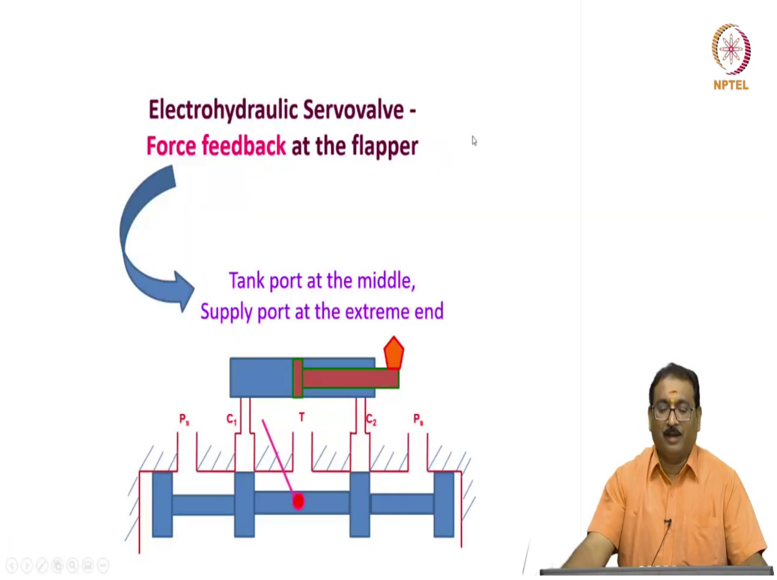


Now, I will show you one more configuration here. The tank port is at the middle, previously extreme end of the spool, now it is tank port is at the middle pressure ports are at the extreme end of the spool.

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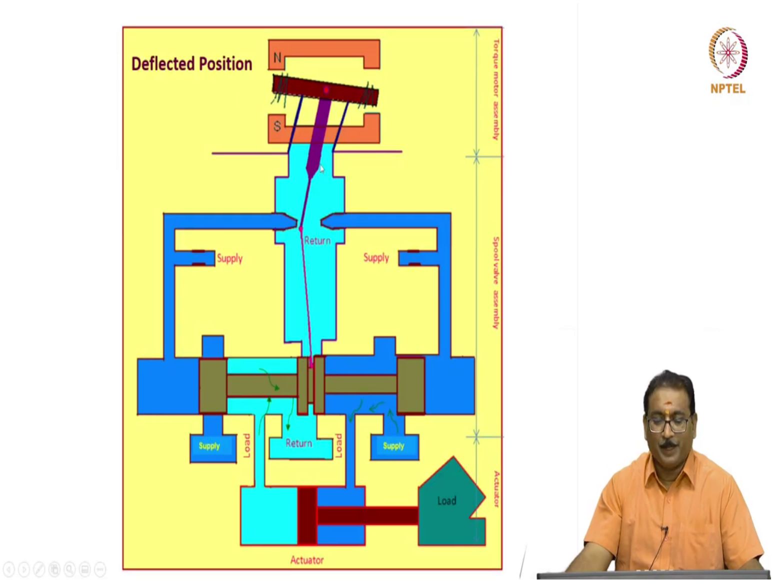


Now, we will see friends here again and deflected position I have shown you, same concepts correct. The pressure will starts building, moving here, when it will move here, what happens? The supply port now we will see here come to the load, it will push, whatever the flow will come here, it will go to the return, return is at the middle. Same thing, again the movement of the spool pushes the feedback spring to bring the flapper to the null position for any current input.

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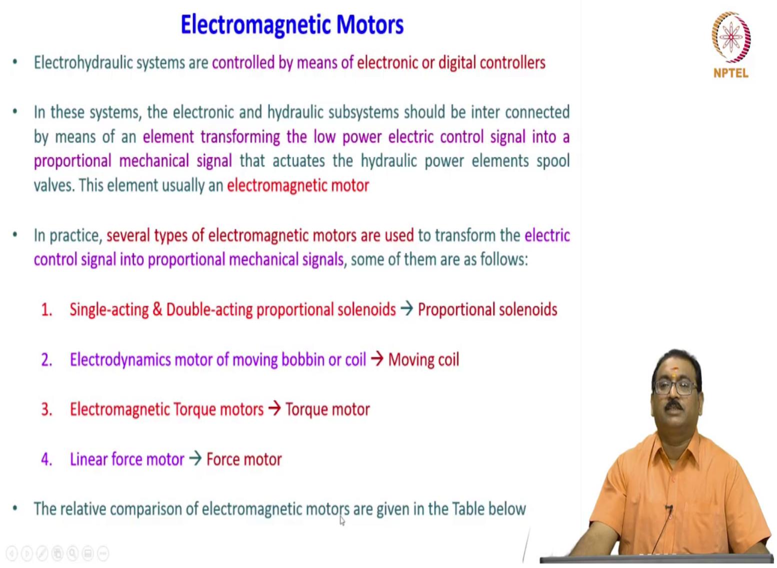


Now, we will see the different types of electromagnetic motors are available to stroke the spool. Electrohydraulic systems are controlled by means of electronic or a digital controllers. In these systems, the electronic and a hydraulics subsystems should be inter connected by means of an element transforming the low power electric control signal into a proportional mechanical signal that actuates the hydraulic power elements spool valves, this element usually an electromagnetic motor.

In practice, several types of electromagnetic motors are used to transform the electrical control signal into proportional mechanical signals, some of them are as follows. Single and a double acting proportional solenoids.

As we have seen many are used in the proportional solenoids. Electrodynamic motor of moving bobbin or a coil, moving coil. Electromagnetic torque motors and in torque motors.

Linear force motor, force motors. The relative comparison of these electromagnetic motors are given in the table below.

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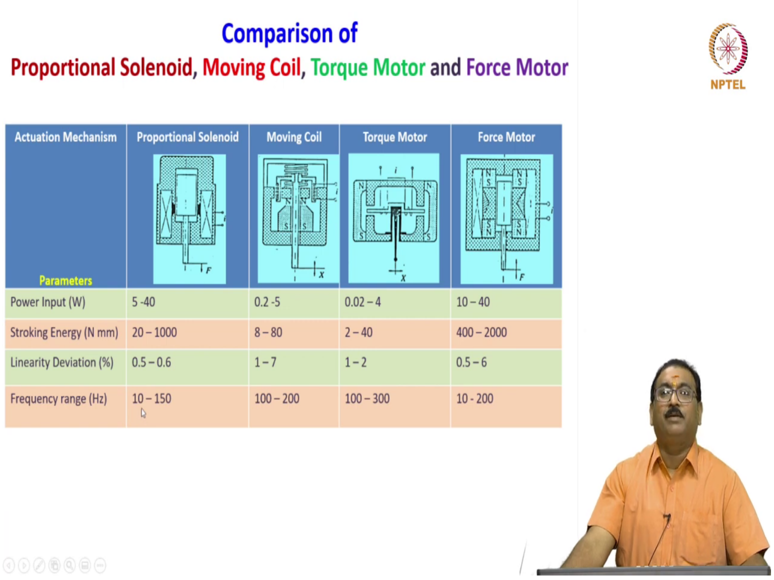


Now, we will see the comparison. I am giving you the different actuation mechanism, proportional, moving, torque motor and a force motor, all are the electromagnetic motors. Parameters I am giving here, power input for proportional is 5 to 40, moving coil 0.2 to 5 Watt or torque motor 0.02 to 4 Watts, force motor 10 to 40 Watts. Similarly, stroking energy in Newton meter 20 to 1000 for the proportional, moving coil 8 to 80, torque motor 2 to 40 and force motor 400 to 2000.

Linearity deviation you will see in percentage, for proportional solenoid 0.5 to 0.6, moving coil 1 to 7, torque motor 1 to 2, force motor 0.5 to 6. Frequency range in terms of hertz, proportional valve 10 to 150, moving coil 100 to 200, torque motor you will see here 100

Hertz to 300 Hertz, force motor 10 to 200 Hertz. Torque motor property, you will see is a better than the other thing that is why they are used more frequently in the electrohydraulic servo system.

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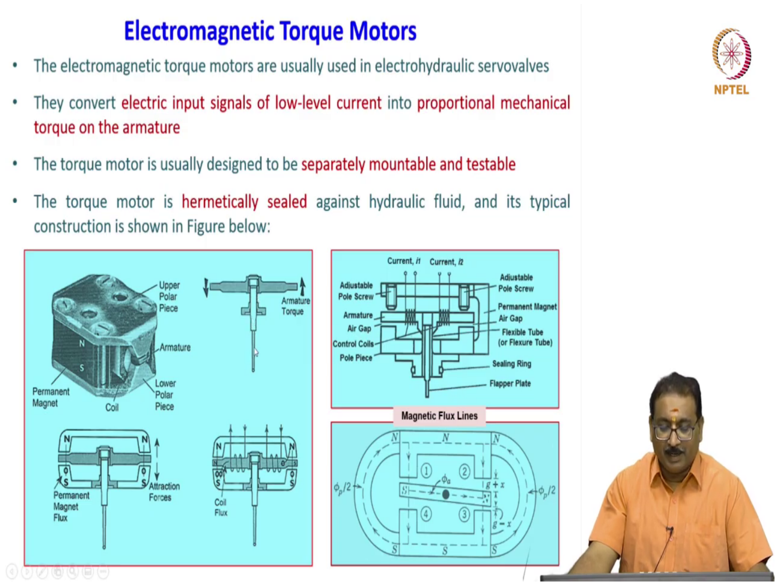


Quickly I will tell you what is this electromagnetic torque motors. The electromagnetic torque motors are usually used in electrohydraulic servovalves. They convert electrical input signals of low-level current into proportional mechanical torque on the armature. The torque motor is usually designed to be separately mountable and testable. The torque motor is hermetically sealed against hydraulic fluid and its typical construction is shown in figure below.

You will see here the assembled one, upper pole piece and lower pole piece. You will see here armature is held between the pole piece. Then is the coils are there correct on the both side.

You will see here, this is the armature mounted on the flexural tube and this is a flapper and backside is a feedback spring. How the torque is applied? You will see. Here, you will see the north pole piece, south pole piece and they are charged with the U-type magnets, permanent magnets are there here, they will rotate by applying the current in the coils, you will see here i 1 and i 2 coils.

Now, we will see here friends, the adjustable pole pieces are also available in the market, you have to adjust the air gap. Air gap here, how many air gaps are there friends? The four air gaps. You will see here, one air gap, second, third, fourth you will see here I marked here one, two, three, four air gaps meaning the armature is held middle in the null position, all four air gaps one, two, three, four are balanced meaning it is held in the air in nothing but.

When you apply the current, this will armature will move correct here friends, this is the flapper as I have told you know, it is a ceiling ring. Now, we will see here I have shown the magnetic flux lines also once you supply the current to the coils of the armature. You will see how it is, then you will see here already this is a ferromagnetic material armature when you will energize, how it will go? Flux lines will go here like this south to north, then it will follow like this that time it is created as a south.

Then here also, you will see how the lines will move? It will go here, go here and go here and go correct friends. You will see here this here if it is a g minus x, it is a g plus x, x is a movement properly, then you will see equal air gaps, this gap is equal to this, this gap equal to this meaning if it is a g minus x, this is also g minus x. If it is a g plus x, this is also g plus x meaning it is a movement of the armature in the air gap, equal air gap always there.

Then, you will see here when it will create south, it will move from souths to north along the arma, pi a is a the flux line on the armature, phi p is a the flux line in the pole pieces, phi p by 2 here, phi p by 2 here, equally.

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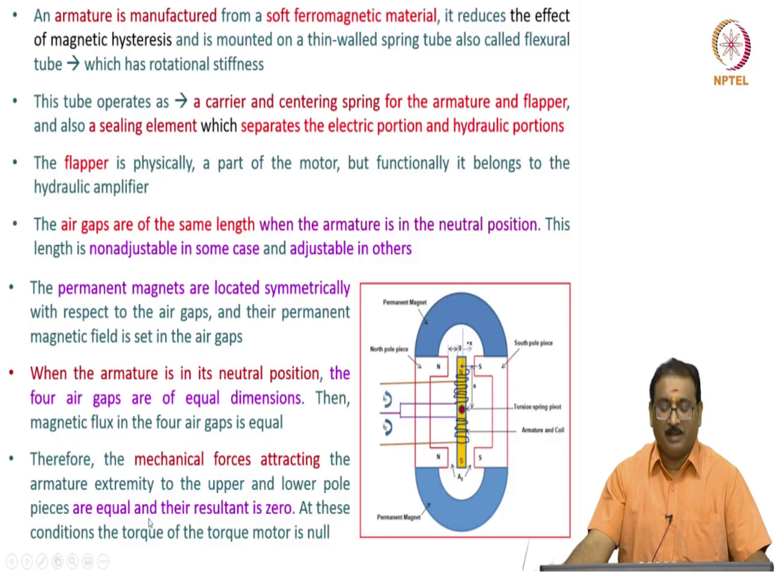


Now, we will quickly see the an armature is manufactured from a soft ferromagnetic material, it reduces the effect of magnetic hysteresis and is mounted on a thin-walled spring tube also called a flexural tube which has a rotational stiffness.

This tube operates as a carrier and a centering spring for the armature and a flapper and also a sealing element which separates the electric portion and hydraulic portion. The flapper is a physically, a part of the motor, but functionally it belongs to the hydraulic amplifier to creates the pressure across the spool end.

The air gaps, you will see here air gaps I have shown you g, g is an air gap of the same length when the armature is in the neutral position. This length is non-adjustable in some cases and adjustable in the other cases. The permanent magnets are located symmetrically with respect to the air gaps and their permanent magnetic field is set in the air gaps.

When the armature is in its neutral position, neutral means here neutral position, the four air gaps are equal dimension, these are all four air gaps are in equal dimension meaning area of the air gaps are equal when the armature is at the middle, it will rotate through the i 1 and i 2 current. Therefore, the mechanical forces attracting the armature extremity to the upper and a lower pole pieces are equal, and their resultant is zero. At these condition, the torque of the torque motor is null.

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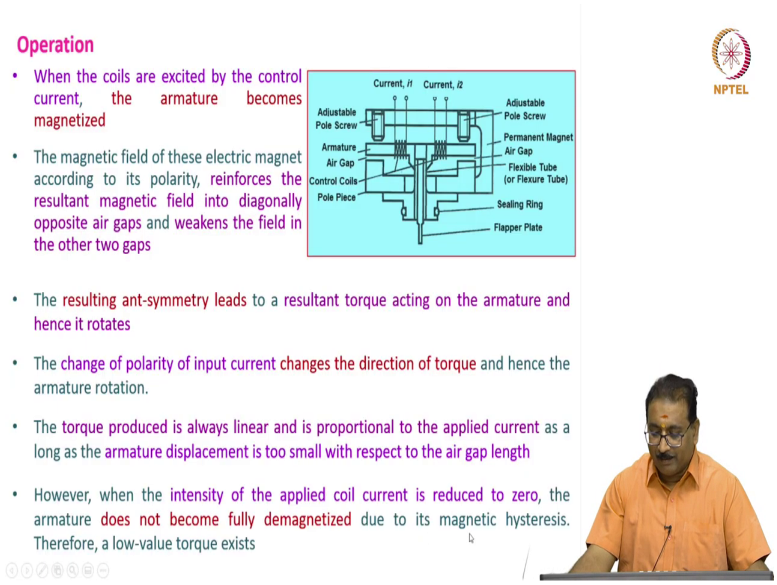


So, operation you will see, how it will operate? As I have told you, by passing the current i 1 and i 2 for the polarity. Polarity field change, it will rotate in the other direction. What is the polarity? If i 1 is greater than i 2, it will rotate in one direction. If i 2 is greater than i 1, it will rotate in the other direction meaning whole objective is to move the flapper to the left side or a right side to close the nozzles.

When the coils are excited by the control current, the armature becomes magnetized. The magnetic field of these electric magnet according to its polarity, reinforces the resultant magnetic field into diagonally opposite air gaps and weakens the field in the other two gaps. The resulting anti-symmetric leads to the resulting torque acting on the armature and hence it rotates.

The change of polarity of input current changes the direction of torque and hence the armature rotation. The torque produced is always linear and is proportional to the applied current as long as the armature displacement is too small with respect to the air gap length. However, when the intensity of the applied coil current is reduced to zero, the armature does not become fully demagnetized due to its magnetic hysteresis. Therefore, a low value torque exists.

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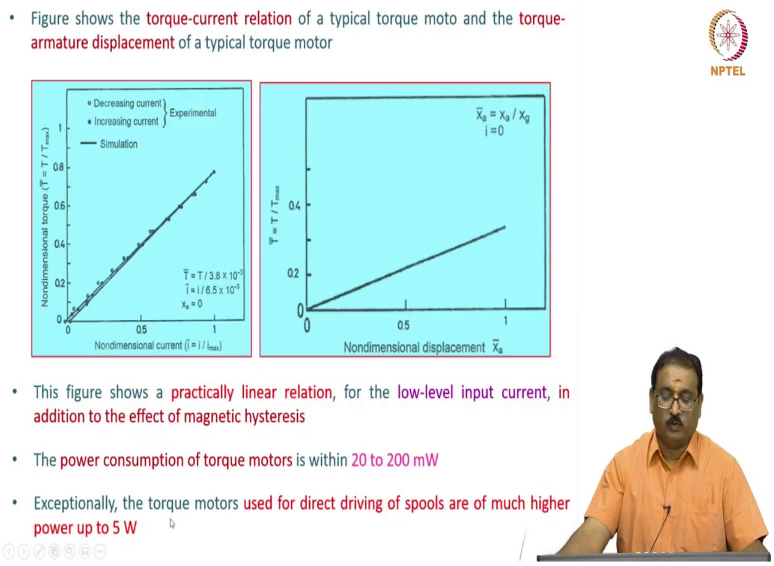


Figure shows the torque current relationship of a typical torque motor and the torque armature displacement of a typical torque motor. You will see here, I am taking here a non-dimensional torque and a non-dimensional current, torque and current.

You will see the relationship, how it will go. Proportionately, it is going torque is creating through the current. Similarly, you will see the non-dimensional displacement of the armature linearly it will go. This figure shows a practically a linear relation, for the low-level input current in addition to the effect of magnetic hysteresis. The power consumption of a torque motors is within 20 to 200 milli Watt. Exceptionally, the torque motors used for driving the spools are much higher power up to 5 Watt also.

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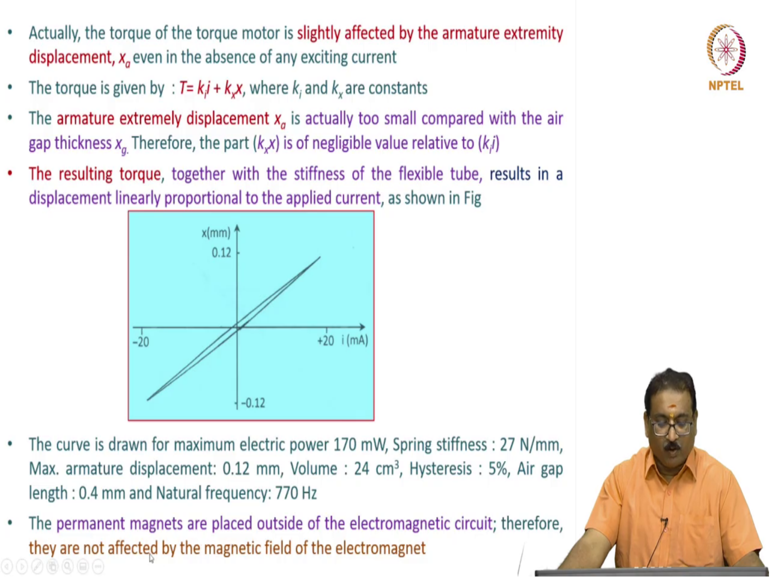


Actually, the torque of the torque motor is slightly affected by the armature extremity displacement, x a even in the absence of any exciting current. The torque is given by T equal to k i into i plus k x into x where k i and k x are the torque motor constants. The armature extremity displacement x a is actually too small compared with the air gap lengths x g. Therefore, the part k x into x is negligible value relative to the k i into i.

The resulting torque, together with the stiffness of the fractural tube, resulting in a displacement proportional to the applied current, as I have shown you linear relationship. Here, I am showing you as the current is goes on increasing in one side and decreasing in the other side. It is a if polarity will change, it will go to the other side. This is a displacement versus the current. Here current is 20 milli Amp maximum. Displacement of the armature as I have told you less than 0.12 mm.

The curve is drawn for a maximum electric power 170 milli Watt, spring stiffness 27 Newton mm, maximum armature displacement 0.12, volume is 24 cubic centimeter, hysteresis 5 percent, air gap length is 0.4 mm, natural frequency 770 Hertz. Th e permanent magnets are placed outside of the electromagnetic circuit; therefore, they are not affected by the magnetic field of the electromagnet.