Oil Hydraulics and Pneumatics
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Electro Hydraulic Servo Valve (EHSV)
Lecture - 91
Part 3: Differential pressure across spool end, Jet pipe electrohydraulic servovalve – constructions and operations, First-stage: Pressure and flow variations

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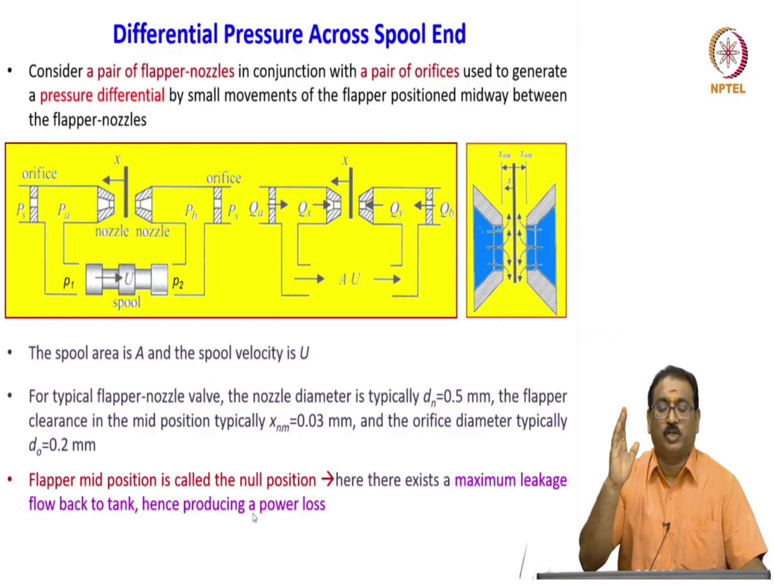

My name is Somashekhar, course faculty for this course. Then, quickly I will show you, after knowing the torque motor we will see the differential pressure across the spool end. Consider a pair of flapper-nozzles in conjunction with the pair of orifices used to generate a pressure differential by small movement of the flapper positioned midway between the flapper-nozzles.

You will see here, I have shown you the figure of the flapper-nozzle valve. This is the flapper nozzle valve it will rotate here or rotate here, any direction. These are the nozzles and these are the orifices. From the supply it will come here it will go. In the null position, large amount of null flow is going to the tank. This is a spool valve, U is the velocity. How it will be moved?

When the torque when the torque motor is energized flapper will move this side or this side; for example, if it will move this side the pressure will builds here P 1 is greater than P 2 it will move, correct. Now, here I am showing you A into U, A is the area of the spool pi by 4 dP square and U is the velocity.

Here I have shown you the this is the flapper. The distance between the flapper to the nozzle is x nm, x nm, when the null position x nm both side it is equal, ok friends. Let us we will see, here the flow is Q a and Q b. Q x from the nozzle and Q y from the nozzle, this is the orifice flow. Let us we will see the dynamics of the spool movements. The spool area is A and a spool velocity is U.

For a typical flapper nozzle valve, the nozzle diameter is typically 0.5 mm and the flapper clearance in the mid position typically x nm is 0.03 and the orifice diameter typically 0.2 mm, you will see nozzle diameter is given orifice diameters. Flapper mid position is called the null position. Here, there exists a maximum leakage flow to the tank, and hence producing a power loss in the middle positions.

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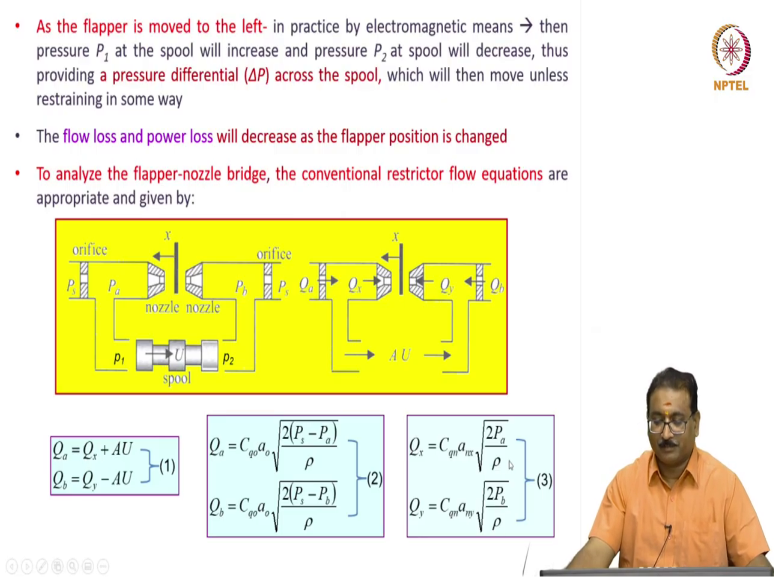

So, as the flapper is moved to the left, in practice by electromagnetic means then the pressure P 1 at the spool will increase and pressure P 2 at the spool will decrease, thus providing a delta P across the spool valve, which will then moves unless restraining in some way. The flow loss and a power loss will decrease as the flapper position is changed.

To analyze the flapper-nozzle bridge, the conventional restrictor flow equations are approximated and give by you will see here the Q a and Q b, Q x this is plus A into U, here proportionately the spool velocity is minus A into U then, how to calculate the Q a here? Q a is the C q naught a naught root of 2P s minus P a, P s is a the supply pressure, P a is pressure at this side. You will see, rho is a density of the fluid.

Similarly, the Q b on the other side here, you will see here the Q b here whatever it is coming from this orifice same way C q naught o, a naught into root of 2P s minus P b divided by the rho; similarly, how we will calculate the Q x and Q y here? C qm it is a coefficient at the nozzle. This is a coefficient at the orifice a nx here a ny root of 2P a divided by rho or 2P b by rho, same way it is.

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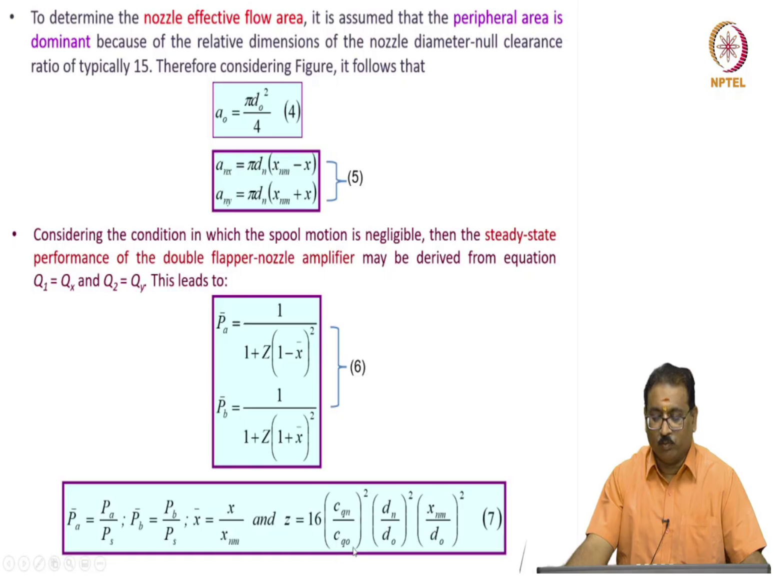

Now, you will see friends, to determine the nozzle effective flow area, it is assumed that the peripheral area is dominant, because of the relative dimensions of the nozzle diameter that is the null clearance ratio of typically 15. Therefore, considering the figure it follows that a naught equal to pi by 4 d o square. The perimeter here a ns is pi d n, x nm minus x, maximum displacement of the nozzle then how much it is moved. Similarly, it will pass correct equal proportionate here.

Considering the condition in which the spool motion is negligible, then the steady state performance of the double flapper-nozzle amplifier may be derived from the equation Q 1 equal to Q x Q 2 equal to Q y. This leads to P a bar 1 divided by 1 plus Z into 1 minus x bar into whole square. Similarly, here 1 plus, P a and P bar are the average pressures.

You will see here P a bar is P a by P s supply non-dimensional value, P b bar equal to P b by P s; x bar equal to x by x nm, this is the maximum displacement and how much it is moved. Z is 16 into c qn by c qo whole square or d n square by d o square into x nm by d o square.

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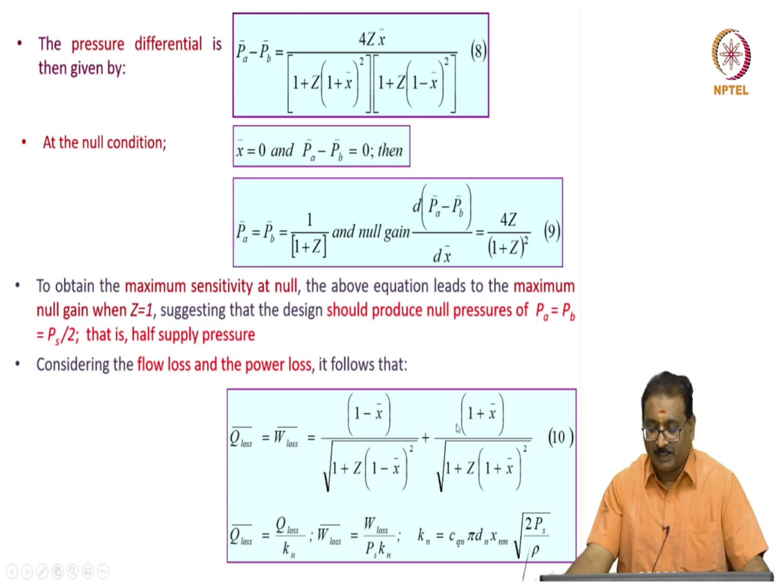

The pressure differential is then given by P a bar minus P b bar. This is an equation. At the null condition, meaning x bar is 0, P a bar minus P b bar is 0, then the spool will not move that is why I am telling you. Then, P a bar equal to P b bar in the null position this is 1 divided by 1 plus Z. And the null gain is differentiate P a bar P b bar what you are getting with respect to x bar. We will get it 4 Z divided by 1 plus Z whole square.

To obtain the maximum sensitivity at null, the above equation leads to the maximum null gain when Z equal to 1, suggesting that the design should produce a null pressures of P a equal to P b, that is equal to P s by 2 that is half the supply pressure. Considering the flow loss and a power loss, it follows, the flow loss Q bar equal to W bar loss equal to 1 minus x bar the thing 1 plus Z, 1 minus x bar.

Here it will be here it is same though plus correct. As I have to do, symmetry is there here. Then Q bar loss is equal to Q loss by k n, W bar loss equal to W loss by P s into k n; k n is a c qn pi d n x nm root of 2 P s by rho.

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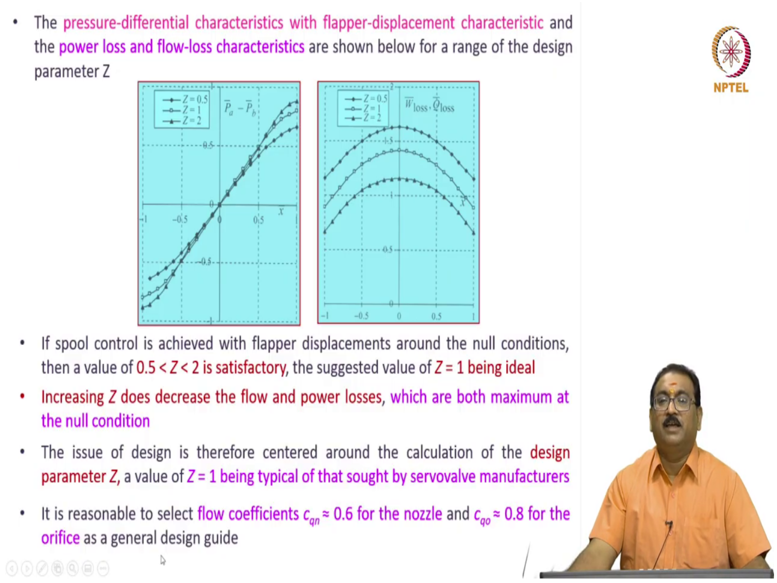

The pressure-differential characteristics with a flapper displacement characteristics and the power loss and a flow loss are shown for a range of the design parameters Z. For example, Z equal to 0.5, Z equal to 1, Z equal to 2, how my P a bar minus P b bar across the spool.

You will see here, how the linearity is there. In the null position it is 0, then it is differential pressure is increasing. Later at the later stage you will not get the proper you know linearity. Always you will see here in the mid position the losses are maximum. If the spool control is achieved with flapper displacement around the null conditions, then a value of Z is greater than 0.5 or less than 2 is satisfactory, the suggested value of Z equal to 1 being ideal.

Increasing Z does decrease the flow and power losses, which are both maximum at the null condition. The issue of design is therefore, centered around the calculation of the design parameter Z, a value of Z equal to 1 being typically of that sought by the servo valve manufacturers. It is reasonable to select the flow coefficient c qn equal to approximatively 0.6 for the nozzle and c qo for 0.8 for the orifice as a general design guide.

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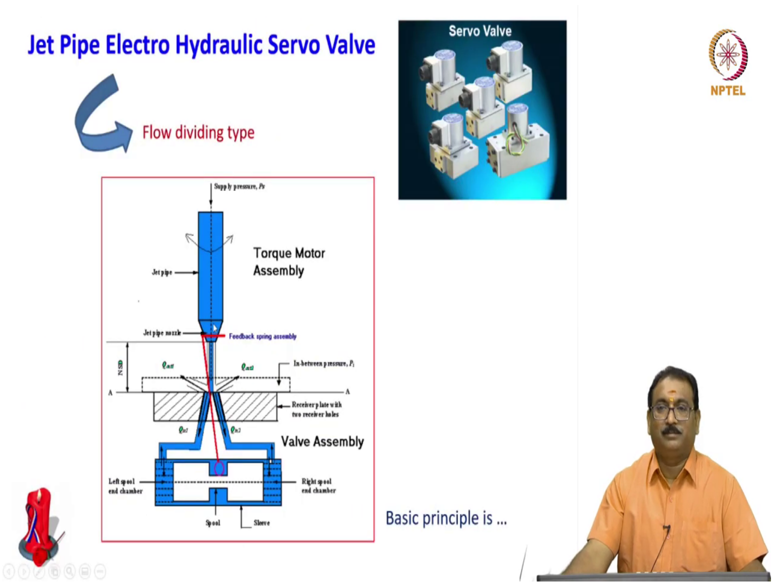

Now, quickly we will see the one more servo valve jet pipe electro hydraulic servo valve. It is a flow dividing type. You will see here friends, this is a jet pipe which will carries a fluid continuously, and impinging on the plate this is called a receiver plate which has a two holes. These two holes are connected to the precision spool valve. And then from the jet pipe to the spool there is a feedback spring. Please see here.

This is moved jet pipe will moved over the receiver plate using the torque motor. Meaning two stage valve I am showing you here, first stage is the torque motor assembly, second stage is a valve assembly. Quickly I will show you the operation of this.

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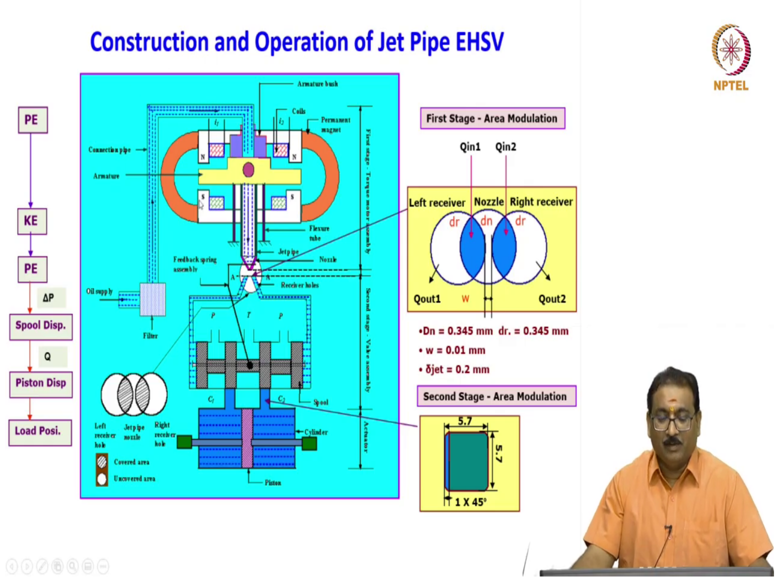

You will see here friends; I have shown detailed view of jet pipe electro hydraulic servo valve. Torque motor as usual I have told you North Pole piece, South Pole piece, this is a armature. These are the air gaps, and here permanent magnets, U type permanent magnets. Then, you will see here this is a flexural tube, flexure tube is there which has a rotational stiffness, which will move along with the armature. Armature is pivoted here and here it is a flow line.

Then beneath this, the second stage what it is? Receiver plate is there two holes connected to the spool end. As the spool valve will move flow is going to the actuator. In the null position; what is the null position? When the jet pipe is at the center equal amount of flow will come to the left receiver and the right receiver as I have shown you here, then spool will not move.

Then no flow is going to the actuator, because it is a null cut servo valve, C 1 and C 2 are completely blocked by the lands.

You will see here friends, here I am showing you the left receiver and a right receiver drilled in the receiver plate. These holes are as close as possible for getting the maximum pressure recovery. And the top of this there is a nozzle. Please see here, top I am showing you, the top side you will see nozzle is coming here. These are the area, these are the opened area correct here, the flow Q in 1, then it will come out as a Q out 1, because no passage here.

After pushing the spool, it will come back and it will go through the opened orifice. Similarly, Q in 2 then after this it will come through opened orifice Q out 2. Over the receiver hole it is a first stage area modulation. For example, if jet pipe nozzle is moving this side, this area is increasing; meaning pressure is increasing in the left receiver. The spool will move proportionately it is decreasing here. Correct here friends. This is the first stage area modulation.

Here, you will see second stage area modulation means when the spool valve will move pores will get opened correct, orifice equation. Here, you do not think always a circular orifice here. The orifice may be the any type based on the customer requirement of the flow, here you will see octagonal port opening. The, you will see here 1 into 45 degree correct, meaning the spool will move in this position only, meaning very very small 0.85 mm on either side of the valve body.

Here, when it will starts moving the area modulation is a second stage area modulation in the two stage servo valve, first stage at the receiver plate, second stage here as the spool will move. The whole basic idea in the jet pipe servo valve is converting the pressure energy into kinetic energy of the jet.

Kinetic energy again converted into the pressure energy in the receiver plate which results in the delta P across the spool. Then, spool will move by the flow, the piston displacement will takes place for load positioning. You will see this is the operation how jet pipe servo valve will work.

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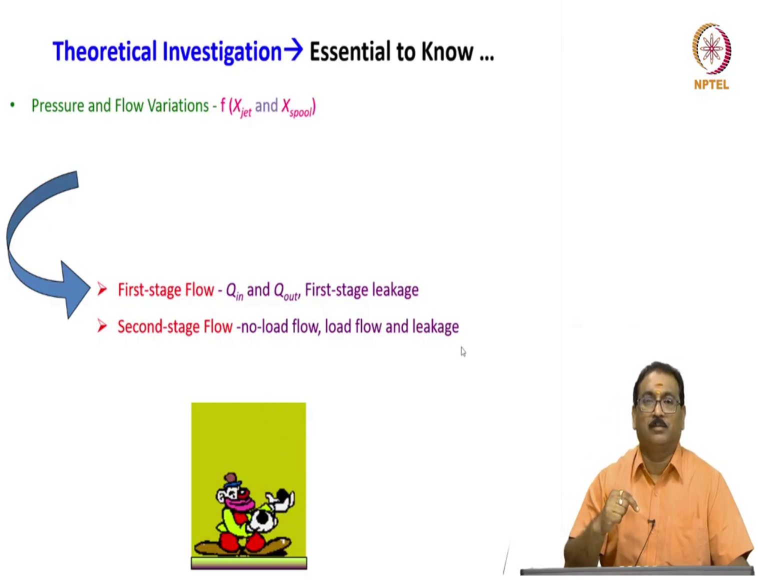

Now, quickly I will tell you the theoretical investigation, essential to know the pressure and flow variations which is a function of jet pipe motion over the receiver plate, as it will the spool will move it will you have to know the what is the pressure and flow is going to the actuator.

So, the first stage flow Q in and Q out, first stage leakage. Second stage flow no load, and a load flow, and a leakage. Leakage means when the spool is at the null position, through the radial clearance between the spool and the valve body always there is a flow, null leakage it is.

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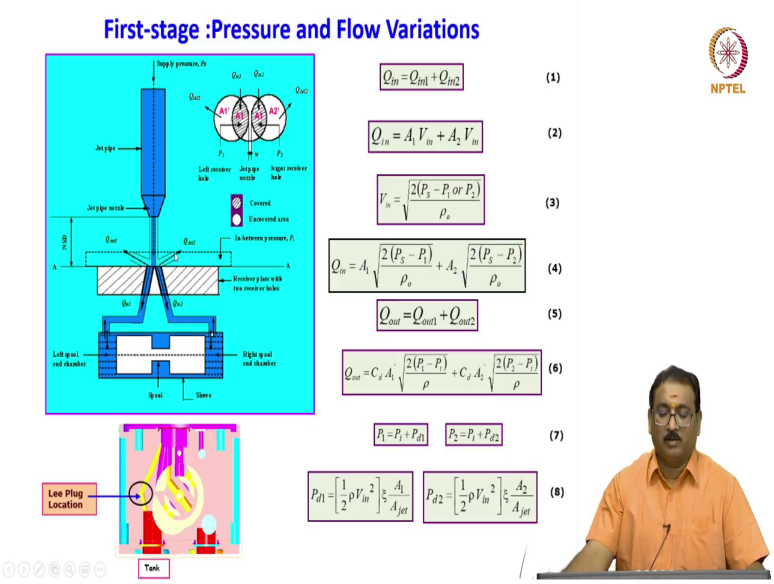

Quickly you will see here friends, I have shown you the jet pipe here, receiver plate here, connected here. You will see here area modulation as I have shown you A 1 and A 2, when the jet pipe is at the middle A 1 equal to A 2 the spool will not move, the flow will come here Q in 1 and go out through the Q out 1, here Q in 2, Q out 2.

The distance between the receiver plate is receiver, the distance between, the distance between the receiver hole is W, it is a web thickness. And please note the nozzle receiver holes all are on the same line to get the maximum pressure recovery. Then after pushing the spool all flow will come here meaning how we will divert to the tank? Always you have to maintain the in between pressure is there, between the nozzle and the receiver plate which will divert the flow through the lee plug to the tank.

Always in between pressure is playing a major role, it will divert the flow back to the tank through the lee plug. Lee plug is an orifice again. Now, we will see friends Q in which is equal to Q in 1 plus Q in 2, how to calculate Q in? A 1 V 1, A 2 V in, correct; A 1 V in, A 2 V in. A 1 and A 2 are the areas V in is the velocity of the jets, which is calculated root of 2 P s minus P 1 or P 2 by rho naught, rho is the density of the oil.

Then, Q in A 1 into root of this I am calculating here. 2 root P s minus P 1 by rho naught plus A 2 into root P s minus P 2 by rho naught. So, Q out is Q out 1 plus Q out 2. How to calculate Q out? Using the simple orifice equation, C d A 1 dash I am using here. This is opened area that is why I am telling A 1 dash, A 2 dash are the opened area. Root of 2 P s P 1 minus P i in between pressure by rho naught plus C d into A 2 into dash root of 2 P 2 minus P 1 by rho naught.

Same fluid of, you do not think rho naught and both are different, both are same. So, the P 1 equal to P i plus P d 1. P d 1 is a dynamic pressures. P 2 equal to P i plus P d 2, P d 1 is 1 by 2 rho V n square into zeta, distributor laws coefficient, A 1 by A jet. P d 2 is 1 by 2 rho V n square zeta A 2 by A jet. Using this equation you have to calculate the pressure and the flow in the jet pipe servo valves.

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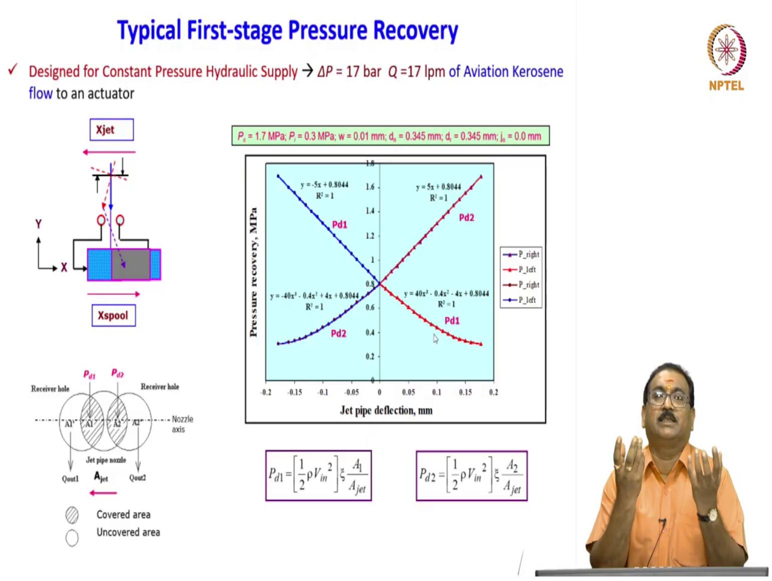

The typical first stage pressure recovery I am shown here, which is designed for the constant pressure hydraulic supply, delta P equal to 17 bar, it will results in 17 liters per minute. When the jet pipe is moved exactly over the one pole, which will create the 17 bar pressure drop which will move the spool as the spool will move it will results in 17 liters per minute of aviation kerosene to the actuator.

Here you will see, as I have shown you when it will this is the area modulation, this is a movement through the torque motor, correct here. You will see whenever the jet pipe is at the middle pressure is equal in the receiver plate. Approximatively, here I am taking the 0.8 MPa it is. When the jet pipe is moved in the assumed to be in the left side, what happen? One side pressure is goes on increasing, other side pressure goes on decreasing proportionately.

Similarly, when the jet pipe will move here one side pressure is goes on increasing, other side pressure goes on decreasing. But you will see some non-linearity is there this non-linearity due to the distance between the two receiver holes. As I have told you this distance is as close as possible to get the maximum pressure recovery.

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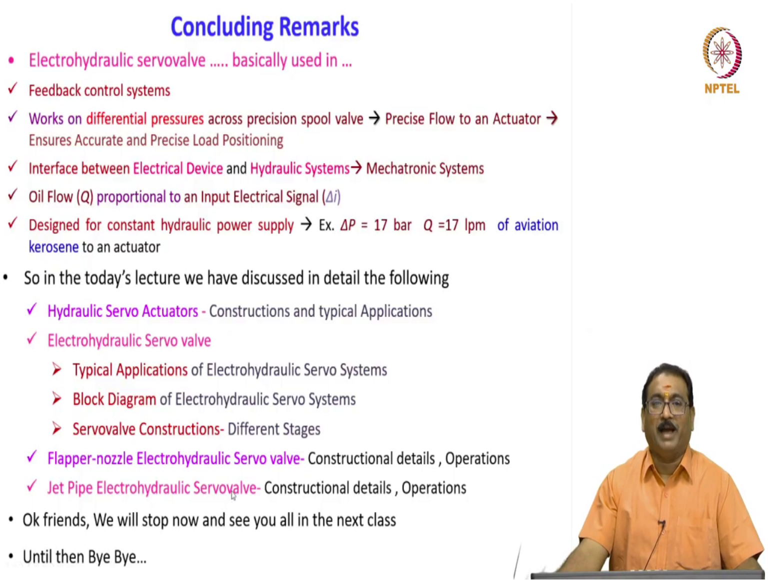

Concluding remarks: Electrohydraulic servo valve basically used in feedback control systems. Works on differential pressure across the precision spool valve, which results in precise flow to an actuator. Ensures accurate and a precise load positioning. Electrohydraulic servo valve is an interface between the electrical device and hydraulic systems generally known as a mechatronic systems. Here oil flow is proportional to the input electrical signals.

Designed for constant hydraulic supply always for example, a 17 bar pressure drop results in 17 liters per minute of aviation kerosene or any fluid to the actuator. So, in today's lecture we have discussed in detail the followings, hydraulic servo actuator, mechanical servos, construction and typical applications, electrohydraulic servo valve,

Typical applications; block diagram, servo valve constructions, different stages, flapper-nozzle electrohydraulic servo valve- constructions, operations, jet pipe electrohydraulic servo valve- constructions, operations.

Ok friends, we will stop now and see you all in the next lecture; until then Bye-Bye.

Thank you one and all for your kind attention [FL].