Oil Hydraulics and Pneumatics
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Part 5: Spool Lap and Flow Characteristics, Leakage through Spool Valve, forces on Spool Valve, Friction, Hydraulic lock, Valve Materials and Specification
Lecture - 36
Directional Control Valves

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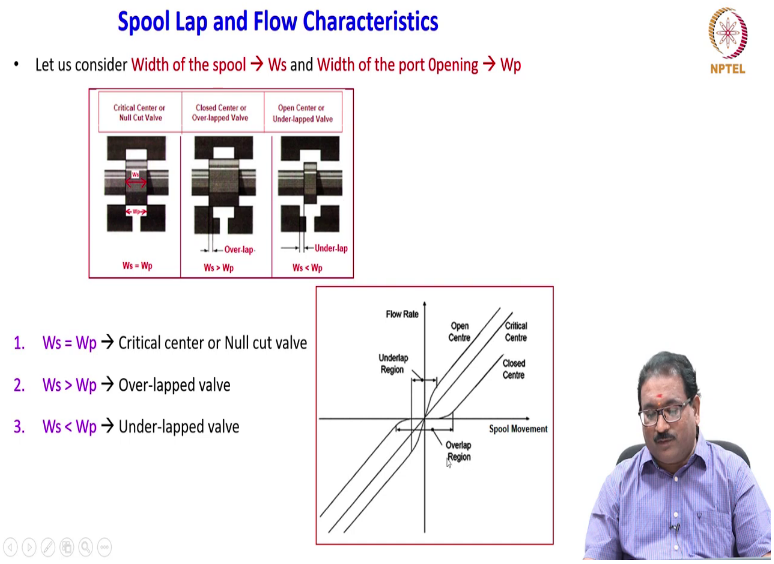

My name is Somashekhar, course faculty for this course. Then very important thing is next to Spool Lap and Flow Characteristics. What is this spool lap? As I have told you, spool land covers the ports, correct? In the valve body. Then lap is very important here, what is this we will see.

Let us consider the width of the spool I am taking, Ws and width of the port opening I am taking Wp. You will see here I am taking here the one land I am taking here friends. This is the port and this is the spool. Ws is a width of the spool, then Wp the width of the port opening. Then when Ws equal to Wp, possibilities are there, correct, when they will ground slowly such a way that the width of the port is equal to width of the spool.

Or if it is less, what happen? You will see, the width of the spool is less than the width of the port, chances are there. If width of the spool, you will see here greater than the width of the port opening, possibilities are there. In such condition if both are equal Ws equal to Wp, it is known as critical center or a null cut valve, which is difficult to achieve because pool is prepared separately, and valve is manufactured separately. Matching these two are very difficult friends.

Such type of valves are there, null cut valves. Response is very good, but generally the spool width is greater than the width of the port that is what you will call overlap. Until you will pass this no flow to the actuator, port will not open, correct. But you will see on the other hand, if the width of the spool is less than the width of the port middle itself, you are getting the flow. It is what you will call this is a open type valve it is.

Now, we will see friends, Ws equal to Wp critically center or a null cut. Ws is greater than Wp overlapped valve. Ws is less than Wp underlapped valve. The flow characteristics, as I have told you it is a spool movement versus the flow rate. In null cut valve Ws equal to Wp, as soon as spool starts moving you will get the linear flow you will see, but in the underlapped valve always there is a flow is there middle you will see flow, then it will starts moving as the spool moves.

But these type of characteristics generally you will see in the servo valves, because here directly valve will get opened; directly valve will get opened. But in overlap, until you will pass this region spool movement will takes place, no flow in case of overlap, this is called as a dead band.

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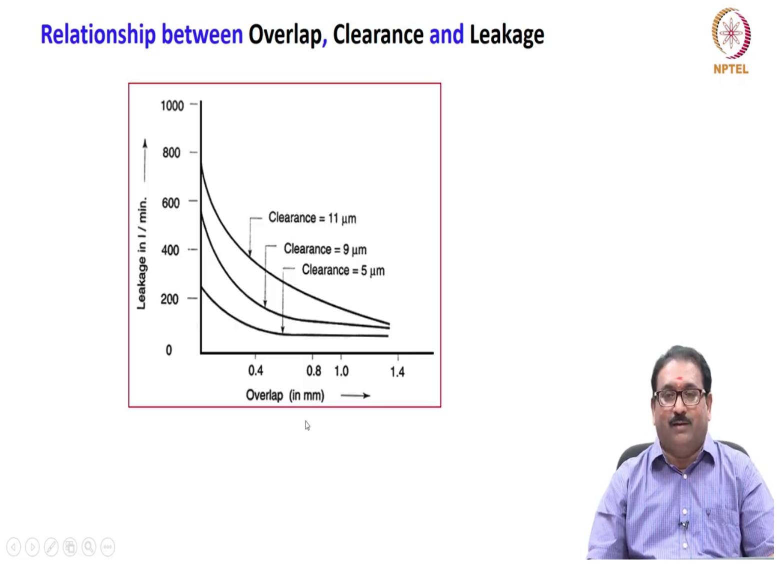

Now, we will see the relationship between the overlap, clearance and a leakage. That this clearance is the distance between the spool and the valve body, meaning diametrical clearance it is. You will see here; the I have drawn the plot here leakage versus the overlap.

As overlap increases the leakage flow decreases. You will see the clearance, the 5 micron clearance this is my the leakage and 9 micrometre this is my leakage and 11 micrometre this is my leakage. Meaning there is a close relationship between the clearance. As clearance radial clearance increases the null leakage will increases, correct. This is case in the spool valve.

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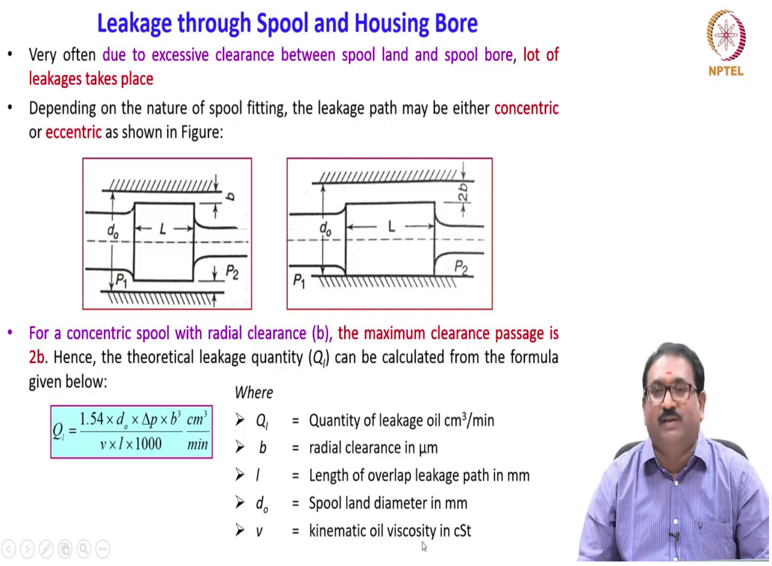

Now, we will see the leakage through the spool and housing bore. Quickly you will see. [FL] Very often due to excessive clearance between the spool land and a spool bore, a lot of leakage takes place. Depending on the nature of the spool fitting, the leakage path may be either concentric or eccentric as shown in the figure here.

You will see here, this is what I will call the concentric, this is spool is stretching here it is eccentric. For the concentric spool with a radial clearance, here you will see the radial clearance, the maximum clearance passage is 2b. Hence the theoretical leakage quantity Q l can be calculated from the formula; Q l equal to 1.54 d o into delta p b cube by nu l into 1000 centimeter cube per minute, because it is a empirical relation to predict the leakage.

When the spool is in concentric the remaining parameter Ql what you will get is a centimeter cube per minute provided you have to use the radial clearance in micron, length of the overlap you take it mm, d naught is a spool land diameter in mm, v naught is a kinematic oil viscosity.

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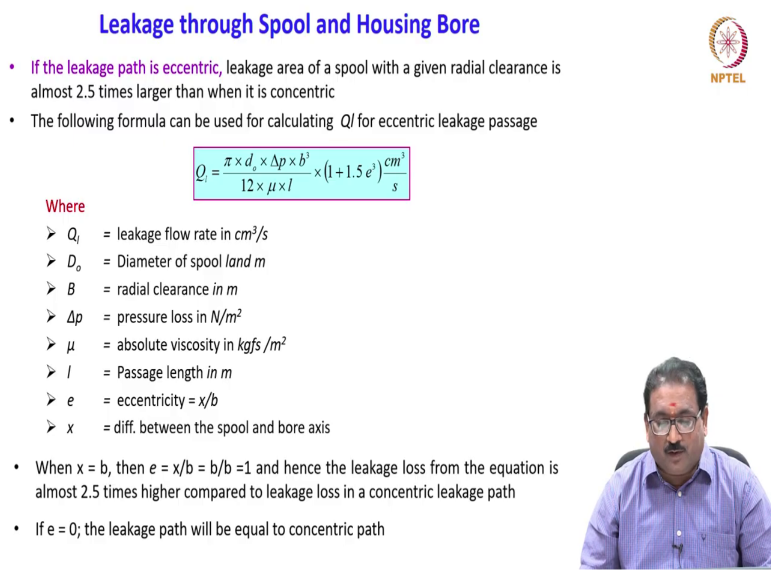

If the leakage path is eccentric, as I have shown you in the previous slide, leakage area of the spool with a given radial clearance is almost 2.5 times larger than when it is concentric. The following formula can be used for calculating the leakage Q l for the eccentric type. Q l equal to pi d o into delta p b cube by 12 mu l into 1 plus 1.5 e cube centimeter cube per second, provided you will use all the quantities in the same units.

Q e centimeter cube per second, D o is a diameter of the spool land in meter, B is a radial clearance pressure loss in Newton per m square, mu is absolute viscosity in kgf second per m square, l is a passage length in meter, e is eccentricity x by b, x is a difference between the spool and the bore axis..

When x equal to b, then what happen? e equal to b by b equal to 1 and hence the leakage loss from the equation is almost, you will see here 1 plus 1.5, it is 2.5 times larger than the leakage loss in the concentric. This is a leakage loss in the concentric. It is how many times? 2.5 times when e equal to 1. If e equal to 0 what happen? The leakage is equal to your concentric path.

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Quickly we will see the sum of the forces on spool. Very often the following forces act on the spool and hence accurate spool positioning can only be achieved by taking into account their spatial futures and influence on the spool movement. First one; forces due to hydraulic imbalance at end chambers caused due to back pressure, flow forces, frictional forces.

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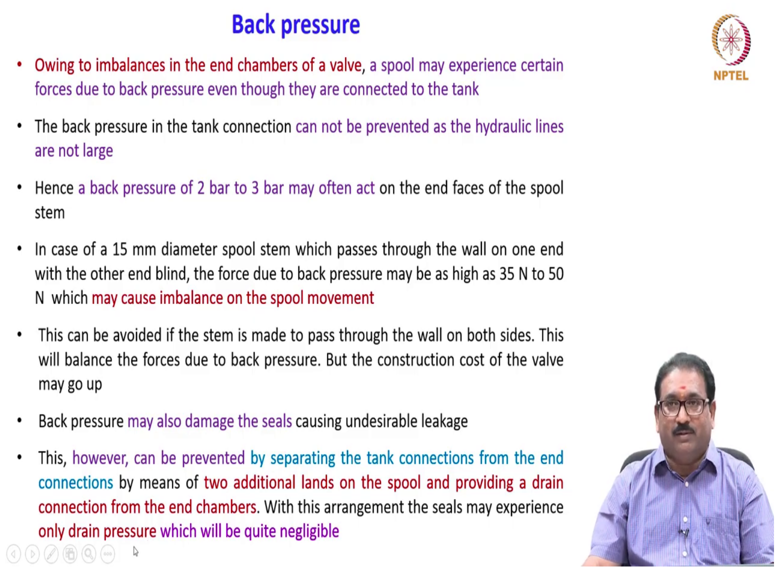

Let us we will discuss these forces in detail. Back pressure; owing to imbalances in the end chambers of the valve, a spool may experience certain forces due to back pressure even though they are connected to the tank. The back pressure in the tank connection cannot be prevented as the hydraulic lines are not large.

Hence, a back pressure of 2 bar to 3 bar may often act on the end faces of the spool stem. In case of 15 mm diameter spool stem which passes through the valve on one end with the other end blind, the force due to back pressure may be as high as 35 Newton to 50 Newton which may cause imbalance on the spool movement.

This can be avoided if the stem is made to pass through the valve on both sides. This will balance the forces due to back pressure. But the construction cost of the valve may go up. Back pressure may also damage the seals causing the undesirable leakage.

This, however, can be prevented by separating the tank connection from the end connection by means of two additional lands on the spool and providing the drain connection from the end chamber. With this arrangement the seals may experience only the drain pressure which will quite negligible.

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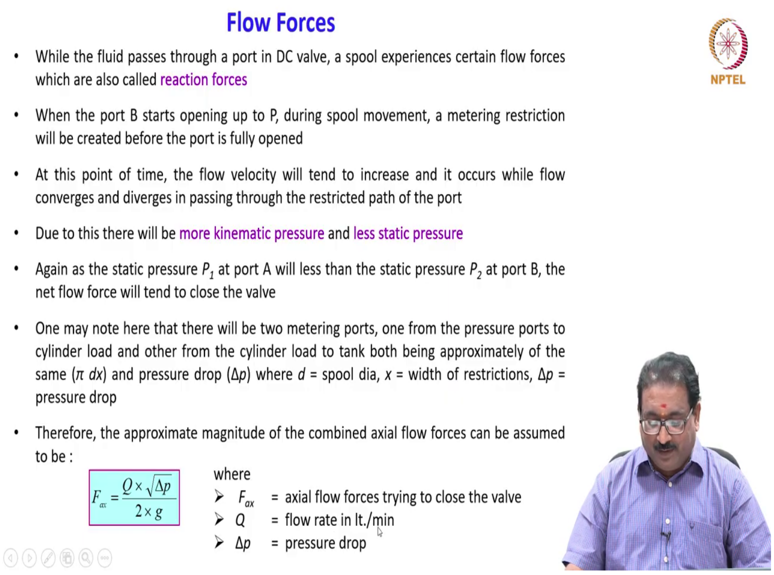

Now, we will move on to the flow forces on the spool. While the fluid passes through a port in directional control valve, a spool experiences a certain flow forces which are also called a reaction forces. When the port B starts opening up to P, during the spool movement, a metering restriction will be created before the port is fully opened.

At this point of time, the flow velocity will tend to increase and it occurs while the flow converges and diverges in a passing through the restricted path of the port. Due to this there will be more kinematic pressure and a less static pressure. Again, as the static pressure P 1 at port A will be less than the static pressure P 2 at port B, the net flow force will tend to close the valve.

One may be noted here that there will be two metering ports; one from the pressure port to cylinder load and other from cylinder load to tank both being approximately of the same pi dx and a pressure drop delta p where d equal to spool diameter, x equal to width of the restriction here and delta p is a pressure drop.

Therefore, the approximate magnitude of the combined axial forces can be assumed to be; F of ax equal to Q into square root of delta p by 2 g. Where F of ax is the axial flow force trying to close the valve and Q is a flow rate in liters per minute and delta p is a pressure drop.

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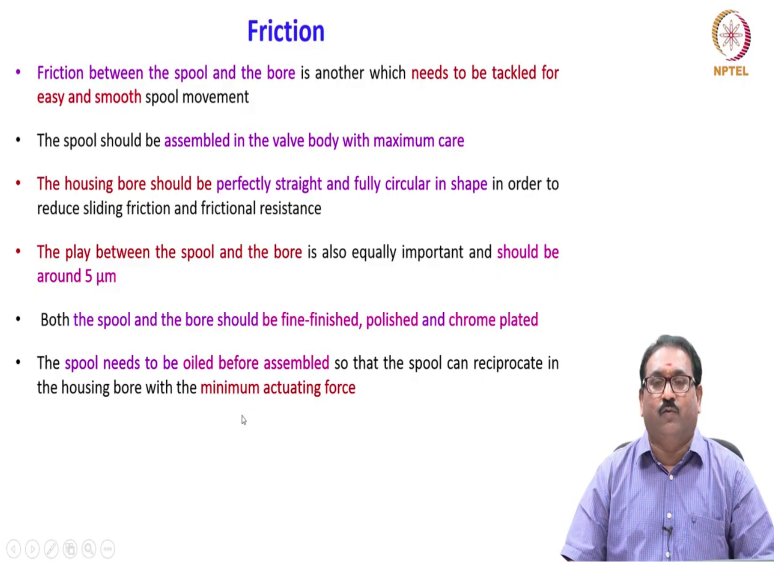

Now, we will move on to the friction between the spool valve and the valve body. Friction between the spool and the bore is a another which needs to be tackled for easy and a smooth spool movement.

The spool should be assembled in the valve body with maximum care. The housing bore should be perfectly straight and fully circular in shape in order to reduce a sliding friction and a frictional resistance. The play between the spool and bore is also equally important and should be around 5 micrometre.

Both the spool and the bore should be fine-finished, polished and chrome plated. The spool needs to be oiled before assembled, so that the spool can reciprocate in the housing bore with a minimum actuating force.

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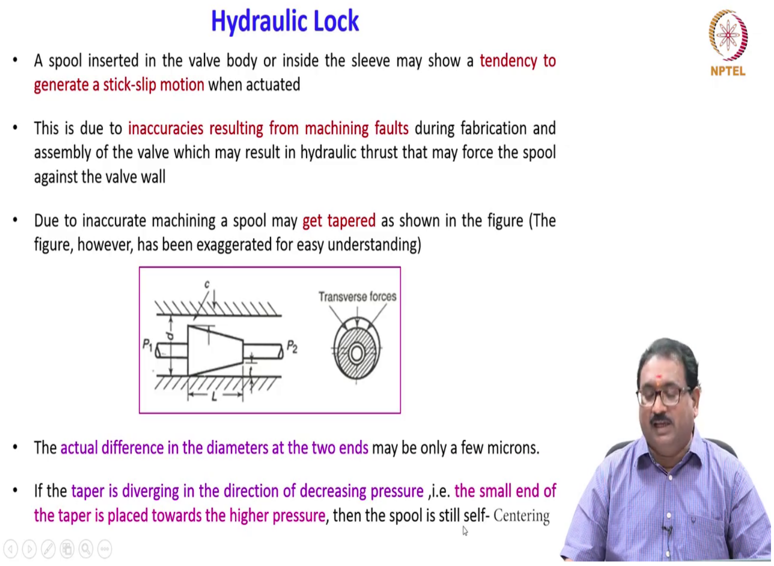

Next important parameter, one more you come across is a hydraulic lock. What is this, what are the causes for it? A spool inserted in the valve body or inside the sleeve may show a tendency to generate a stick slip motion when actuated. This is due to inaccuracies resulting from the machining faults during fabrication and assembly of the valve which may result in hydraulic thrust that may force the spool against the valve.

Due to inaccurate machining of a spool may get tapered as shown in the figure here, but you will remember friends the figure shows; however, exaggerated here tapered ness. The actual difference in the diameters at both ends maybe only a few microns. You will see the clearances here see, here clearance is the t, L is a length P 1, P 2 are the pressures, d is the bore diameter.

If the taper is diverging in the direction of decreasing pressure, that is the small end of the taper is placed towards the higher pressure, then the spool is still self-centering.

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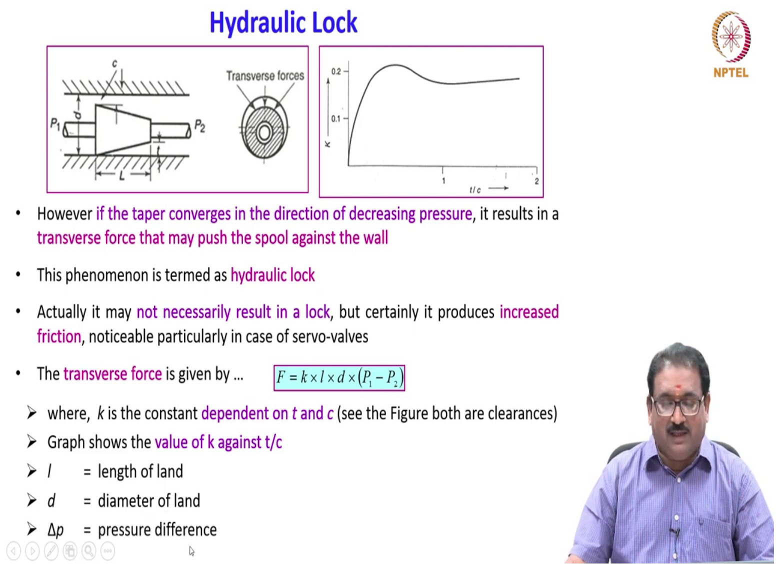

However, if the taper converges in the direction of decreasing pressure, it results in transverse force that may push the spool against the wall. This phenomenon is termed as hydraulic lock. Actually, it may not necessarily result in a lock, but certainly it produces a increased friction and noticeable particularly in case of servo-valves.

The transverse force is given by, F equal to k into l into d into P 1 minus P 2; where, k is a constant depend on t and c, t is the clearance here you will see and here it is c. Graph shows the value of k against t by c, here you will k value how it is changing with respect to t by c, this t by c. The l is the length of the land and d is diameter of the land, delta p is a pressure difference.

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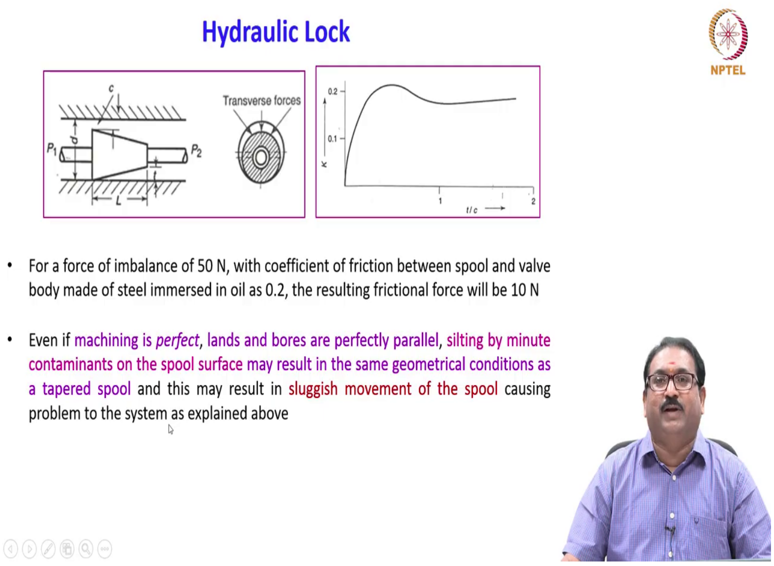

For a force of imbalance of 50 Newton, with a coefficient of friction between the spool and valve body made of steel immersed in oil as 0.2, the resulting frictional force will be 10 Newton.

Even if machining is perfect, lands and bores are perfectly parallel, silting by minute contaminants on the spool surface may result in the same geometrical condition as a tapered spool and this may result in sluggish movement of the spool causing a problem to the system as explained above, meaning hydraulic lock.

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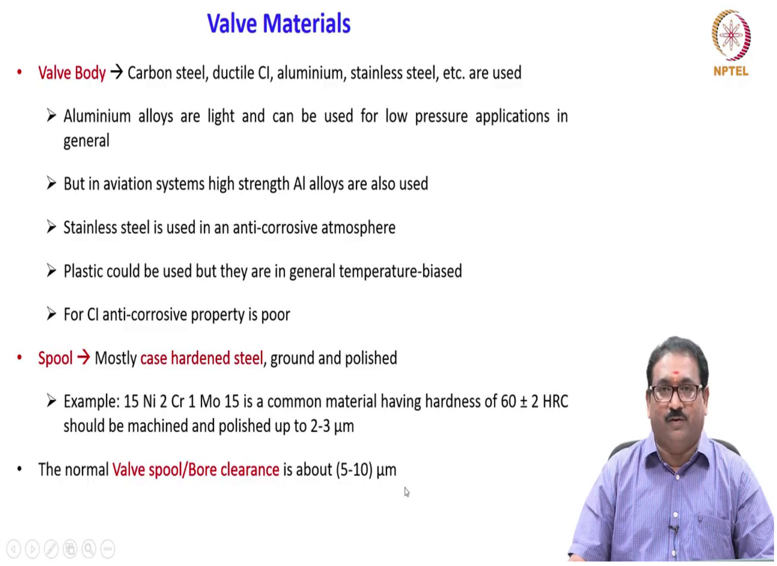

Quickly we will move on to the valve materials. Valve body: generally, carbon steel, ductile CI, aluminum, stainless steel, etcetera are used. Aluminium alloys are light and can be used for low pressure applications in general. But in aviation system high strength aluminium alloys are also used. Stainless steel is used in an anti-corrosive atmosphere. Plastic could be used, but they are in general temperature biased. For CI anti-corrosive property is a poor.

Spool mostly case hardened steel, ground and polished. Example: 15 Ni 2 Cr 1 Mo 15 is a common material having hardness of 60 plus or minus 2 HRC should be machined and polished up to 2 to 3 micron for the spool. This is a case hardened steel. The normal valve spool and a bore clearance is about 5 to 10 micrometre.

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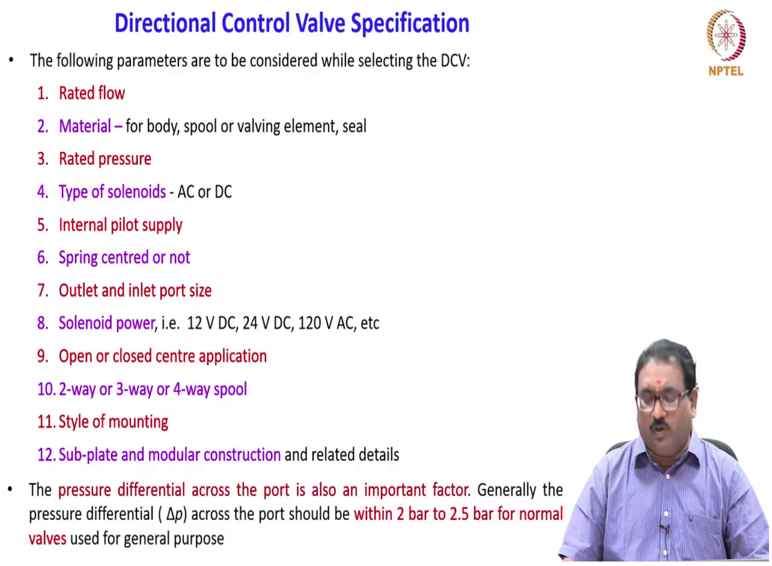

Then quickly we will see the directional control valve specifications. The following parameters are considered while selecting the DCV. Rated flow, material, rated pressure, types of solenoid, internal pilot supply, spring centered or not, outlet and inlet port size, solenoid power, 12 volt DC or 24 volt DC or 120 volt AC, you have to see.

Open or closed center applications, 2-way 3-way 4-way or whatever it is, style of mounting, sub plate mounting, and a modular construction and related details are also collected.

The pressure differential across the port is also important factor. Generally, the pressure differential across the port should be within 2 bar to 2.5 bar for normal valves used for general purpose. These are the important specifications to be keep in mind while selecting the valves for the particular applications.

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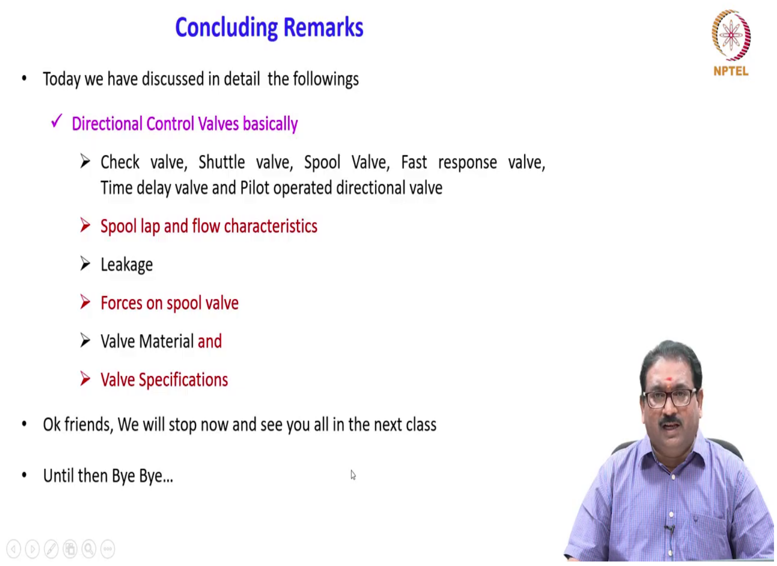

Now, we will conclude today's lecture. Today we have discussed in detail the followings: directional control valves basically; check valve, shuttle valve, spool valves, fast response valve, time delay valve and pilot operated directional valves.

Also, we have seen this spool lap and a flow characteristics. Leakage and how to predict the leakage and forces on the spool valve. Valve material and valve specifications. Ok friends, we will stop now and see you all in the next class, until then bye bye.

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