Oil Hydraulics and Pneumatics
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Hydrostatic Transmissions
Lecture - 83
Part 1: Highlights of HST, Applications, Constructional details of closed-loop HST system, Closed-loop circuit for reversible motor operation, Different pump control method to vary the flow rate, Variable displacement motors in hydraulic transmission

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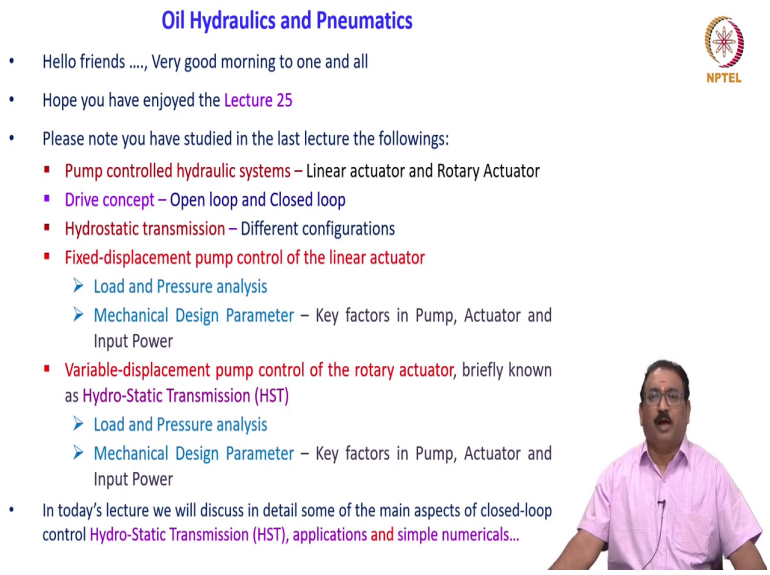

My name is Somashekhar course faculty for this course. Hello friend's very good morning to one and all. Hope you have enjoyed the lecture 25th. Please note, you have studied in the last lecture the followings. Pump controlled, hydraulic systems, linear actuator and rotary actuator, drive concept, open loop and a closed loop.

Hydrostatic transmissions - different configurations, fixed-displacement pump control of the linear actuator. Here we will discussed load and pressure analysis, mechanical design parameters, key parameters of the pump, actuator and input power, then we studied the variable displacement pump control of the rotary actuator, commonly known as the hydrostatic transmissions.

Here also we discussed the load pressure analysis, mechanical design parameters, here also the key parameters of interest are pump actuator and input power. In today's lecture we will discuss in detail some of the main aspects of closed loop hydrostatic transmissions, applications and simple numericals.

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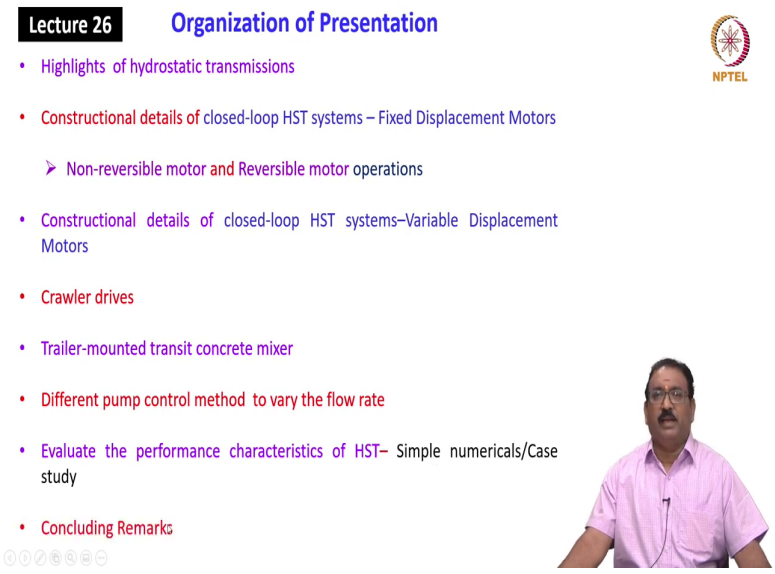

Now, quickly we will see the organization of presentation. Highlights of hydrostatic transmissions, constructional details of closed loop HST systems, here fixed displacement

motors, non-reversible motors and a reversible motor operations, constructional details of closed loop HST systems. Here a variable displacement motors some of the applications of HST in a crawler drives.

Trailer-mounted transit concrete mixer, different pump control method to vary the flow rate. Then, we will move on to the performance prediction of HST with the help of simple numericals and finally, I will conclude the today's lecture.

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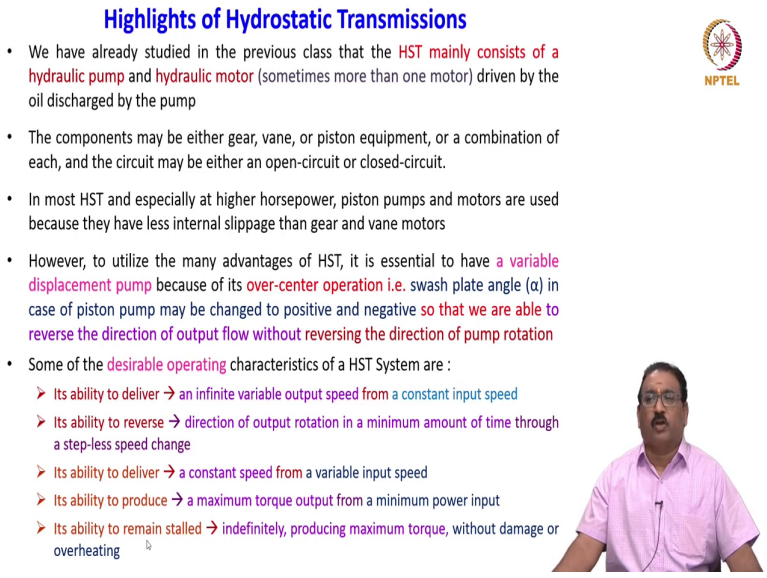

Let us will begin with highlights. We have already discussed in the previous class that, the HST mainly consists of hydraulic pump and hydraulic motor; sometimes more than one motor, driven by the oil discharged by the pump. The components may be either gear, vane, or piston equipment, or a combination of each, and the circuit may be either a open-circuit or a closed-circuit.

In most HST and especially at a higher horsepower, piston pumps and motors are used because they have less internal slippage than gear and vane motors. However, to utilize the many advantages of HST, it is essential to have a variable displacement pump; because of its over-center operation that is already we have seen.

The swash plate angle alpha can be changed based on your requirement to send the flow to the actuator by changing alpha plus or alpha minus. Some of the desirable operating characteristics of the HST system are; its ability to deliver an infinite variable output speed from a constant input speed. Its ability to reverse direction of output rotation in a minimum amount of time through a step less speed change.

Its ability to deliver a constant speed from a variable input speed. Its ability to produce a maximum torque output from a minimum power input. Also its ability to remain stalled indefinitely producing maximum torque without damage or over heating. So, these are the desirable characteristics of the HST systems.

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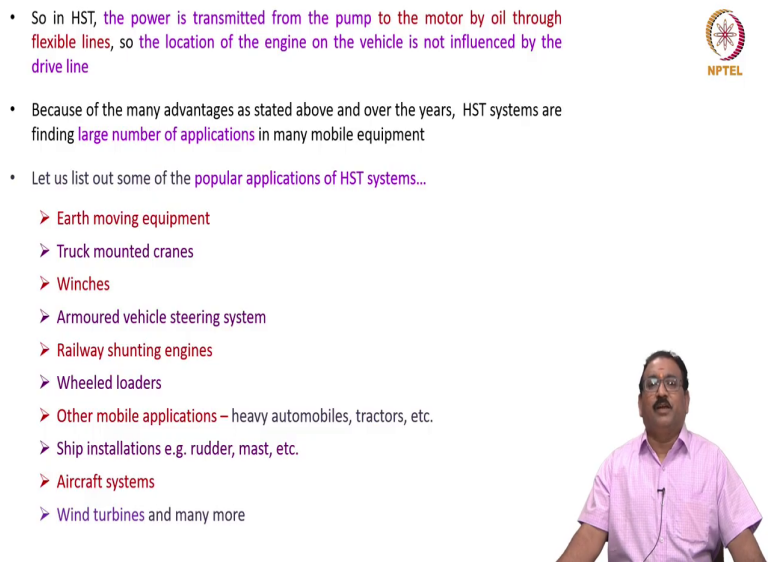

So, in HST the power is transmitted from the pump to the motor by oil through a flexible lines. So, the location of the engine on the vehicle is not influenced by the drive line. Because of the many advantages as stated above and over the years, HST systems are finding a large number of applications in many mobile equipments.

Let us list some of the popular applications of the HST systems are, earth moving equipment truck mounted cranes, winches, Armoured vehicle steering system, railway shunting engines, wheeled loaders, other mobile applications - heavy automobiles, tractors, etcetera. Ship installations example here rudder, mast, etcetera. Aircraft systems last, but not the least the wind turbines and many more.

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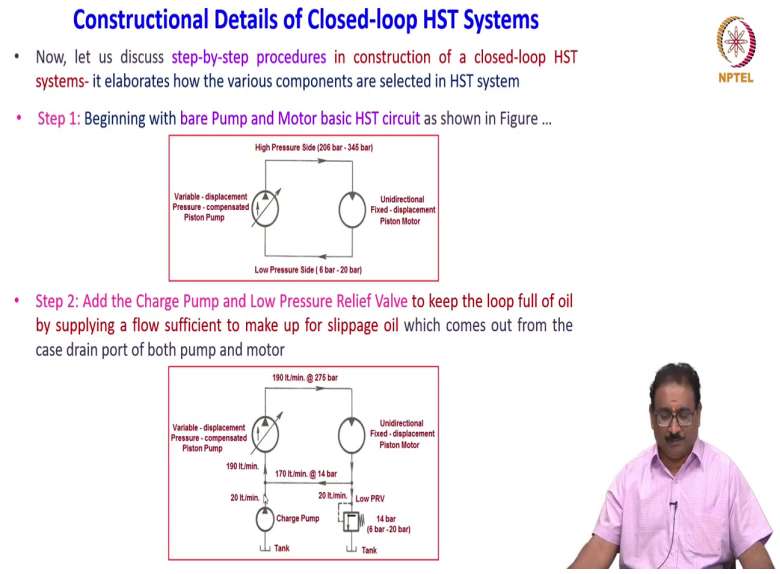

Now, let us we will see friends, how to construct the closed loop HST system based on the applications. Already, we know that, the HST is simply a combination of pump and the motor. Then, how to begin to adding the various components to enhance the performance based on the obligation. Let us we will discuss, now constructional details.

Now, I will give you the step by step procedures in construction of a closed loop HST system. It elaborates how the various components are selected in the HST system. Step 1 begin with the bare pump and motor basic HST circuit as shown in the figure below. Here you will see friends I am controlling the unidirectional fixed displacement piston motor.

Through the variable displacement pressure compensated piston pump. Here you will see the here it is a higher pressure side. The application may call the pressure 2 not 6 to 345 bar. Here

at the after doing the work from the motor, the oil will discharged and enters to the inlet of the pump this is a closed loop. Here the low pressure side may range from 6 bar to 20 bar.

Next add the charge pump and low pressure relief valve to keep the loop full of oil by supplying a flow sufficient to make up for slippage oil, which comes out from the case drain ports of both pump and motor. Meaning why I am adding this change pump and a low pressure relief valve this is to support the variable displacement pump to leakage flow, which occurs in the pump as well as the motor, which will pass to the tank through the drains provided here.

You will see here friends; I am adding here the charge pump and the low pressure relief valve see the positions of these two, because top one is same as above here. Now, you will see friends I am given some of the typical example here, the variable displacement pressure compensated piston pump, produces 190 liters per minute at 275 bar, which is going to the unidirectional fixed displacement piston motor. After doing the work what happens here the oil is low pressure oil it enters, here how much it is?

Now, after counting the leakages 170 liters per minute oil is entering here, but how much it is less here, you will see here 190 is required here 170 other is a leakage. Then, what happens the charged pump will supply to make 190 liters per minute at any instant of time which will go here.

Then also you will see here, whatever the flow is coming here it will go to the low pressure relief valve to the tank. That is why I am writing here you will see here, the pressure setting here it is a 14 bar is generally varies from 6 bar to 20 bar pressure setting. Here you will say 20 liters per minute whatever it is coming here, it will go here.

Meaning here in the all the conditions the oil is full in the loop. This is possible by adding the, the charge pump and low pressure relief valve.

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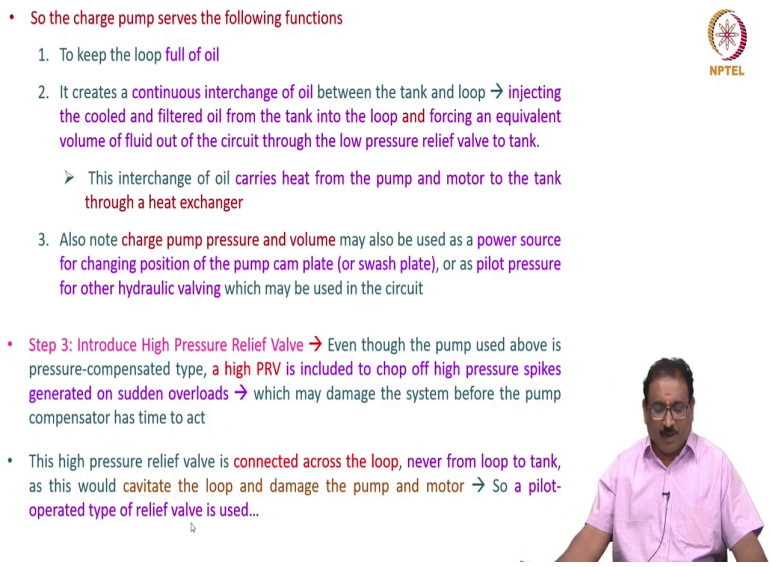

Now, we will move on to the some of the functions of charge pump. Not only supplying the leakage flow. Also it will do the many functions, what are those we will see now. 1st one is to keep the loop full of oil. 2nd it creates a continuous interchange of oil between the tank and loop. Injecting the cooled and filtered oil from the tank into the loop and forcing an equivalent volume of fluid out of the circuit through the low pressure relief valve to tank.

This interchange of oil carries the heat from the pump and motor to the tank through the heat exchangers. Here in the previous figure heat exchangers I have not added, I have add it later. 3rd functions of the charge pump is charge pump pressure and volume may also used as a power source for changing the position of the pump cam plate or a swash plate.

As I have told you the pump cam plate or the swash plate angle is changed used to send the flow to the topside or a bottom side; based on the requirement, meaning alpha plus alpha

negative. This is done through the pressure and volume flow rate from the charge pump or it is used as a pilot pressure for other hydraulic valving, which may be used in the circuit.

Step 3; after adding the charged pump and a low PRV, I am introducing the high pressure relief valve in the basic circuit. What is the need here? Already, we know that even though the pump used above is pressure compensated type. A high pressure relief valve is included to chop off high pressure spikes generated on sudden overloads, which may damage the system before the pump compensator has time to act.

This high pressure valve is connected across the loop, never from the loop to the tank, as this would cavitate the loop and damage the pump and motor. So, a pilot operated type valve is used across the loop.

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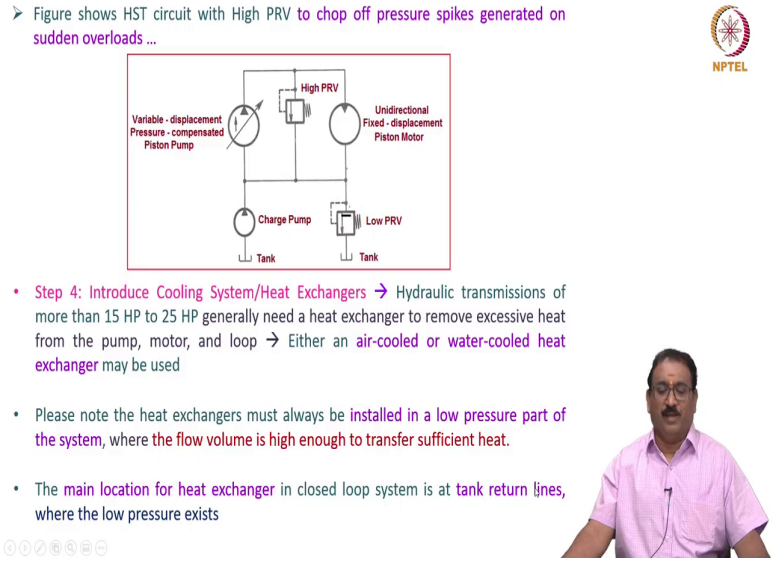

How it is I will show you here. The figure shows the HST circuit with a high PRV, what for it is to chop off the pressure spikes generated on sudden overloads. After adding this, again I am introducing the cooling system or heat exchangers. Why they are required, hydraulic transmissions of more than 15 HP generally need a heat exchanger to remove excess heat from the pump, motor, and loop.

So, either an air cooled or water cooled heat exchangers may be used. Please note friends the heat exchangers must always be installed in a low pressure part of the system. Where, the fluid volume is high enough to transfer a sufficient heat. So, the main location of heat exchanger in a closed loop system is the tank return lines, where the low pressure exists.

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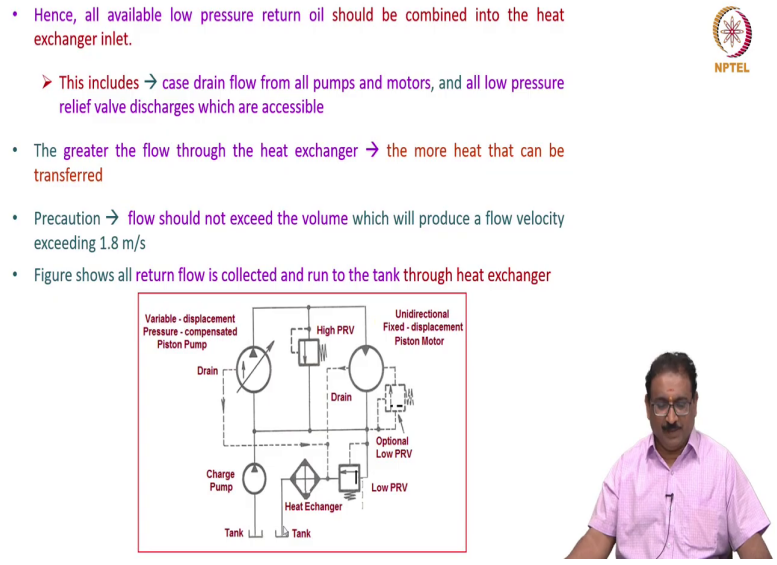

Hence, all the available low pressure return line should be combined into the heat exchanger inlet and then it will go to the tank. This includes the case drain flow from all pumps and

motors. And, all low pressure relief valve discharges, which are accessible. The greater the flow through the heat exchanger, the more heat, that can be transferred.

Precaution here flow should not exceed the volume, which will produce a flow velocity exceeding 1.8 meters per second. Here you will see here, I am adding here the heat exchanger. Where, I am collecting all the drains, from the pump, as well as from the motor and also you will see here the PRV discharges are collected in the inlet of the heat exchanger and it is passed to the tank.

See now friends. How, I am goes on adding the charge pump and low pressure relief valve, high pressure relief valve, now I am adding the heat exchangers, based on the applications.

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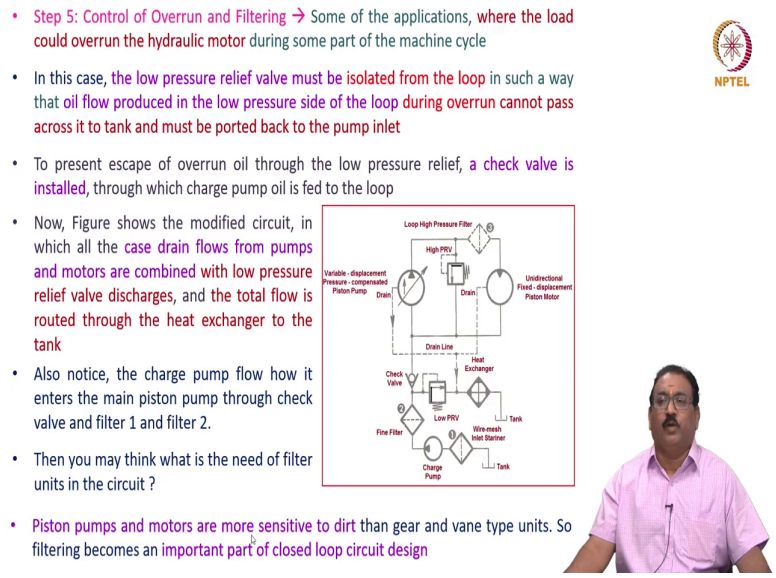

Now, step 5 what I am doing here control of over run and also safeguarding the pump parts and motor parts by adding the filters. 5th step it is some of the applications, where the load could over run the hydraulic motor during some part of the machine cycle. In this case, the low pressure relief valve must be isolated from the loop. In such a way that the oil flow produced in the low pressure side of the loop, during overrun cannot pass across it to the tank.

Must be ported back to the pump inlet, do not send the flow to the tank it will sent to the inlet of the pump. So, to present escape of overrun oil through the low pressure relief valve, a check valve is installed.

Through which charge pump oil is fed to the loop, instead of sending to the tank. Now, we will see here the figure shows a modified circuit in which all the case drain flows from the pumps and a motors are combined with low pressure relief valve dischargers, and the total flow is routed through the heat exchanger to the tank.

You will see here case, the drain from the pump, drain from the motor all are staggered here. Then, the discharges from the low pressure relief valve the to the heat exchanger then to the tank. Also you will see understand friends here what I am doing here, I am adding the check valve. It is a unidirectional valve only flow is going from charge pump to here, it will not possible to move here. The time by passing is the drain all by passing here please understand this.

Also you will see the circuit I am adding the some of the filters. Also notice, the charge pump flow how it enters the main pump flow through the check valve and filter 1 and a filter 2. Then, you may think, what is the need of filter units in the circuit? Already, we know that the filters are used to remove the contaminants it is so, important here. The piston pumps and a motors are more sensitive to dirt, than the gear or a vane pipe units. So, the filtering becomes an important part of closed loop circuit design.

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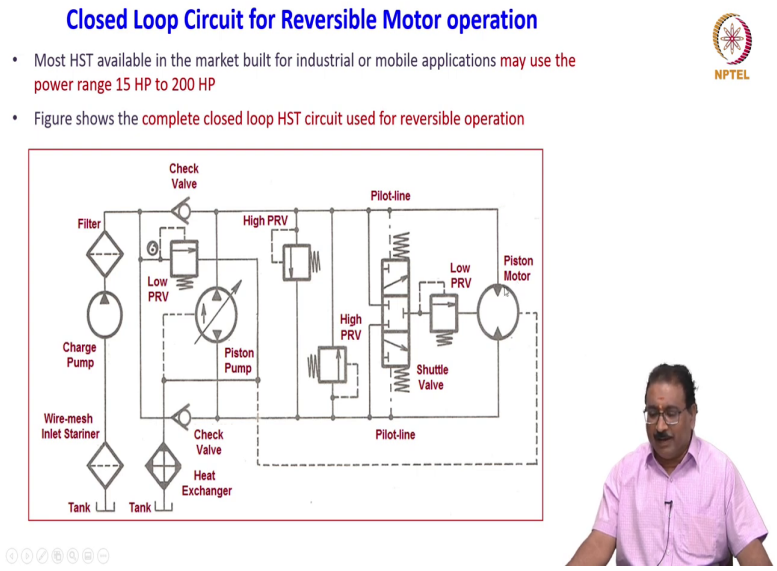

Now, we will see friends, now previously you have seen only non-reversible motor, correct unidirectional motors. Now, I am showing you here, the same concepts. How I am goes on adding the charge pump, low pressure relief valve, high pressure relief valve, and then what it is heat exchangers and how to overcome the over runs and filtering system all are there here also, but here you will see the reversible motor.

Reversible motor means, the flow from the pump it is going from one side it will rotate and then the flow direction is reverse through the over center facility in the pump, it will rotate in the other direction. Meaning I may require now the bidirectional motor correct. Now, we will see most of the HST available in the market built for industrial or a mobile applications may use the power range 15 HP to 200 HP.

Figure shows the complete closed loop HST circuit used for reversible operation of the piston motor. All the elements are there friends whatever I have discussed all are there are here. Let us we will begin here to identify the component. You will see here, this is same as what we have discussed previously.

It is a variable displacement pressure compensated piston pump which will sends the flow. Then this will go to the to piston motor, what type of piston motor it is now it is you will see reversible motor. Reversible means it is a bidirectional motor, whether flow is coming from this side or flow is coming from this side will matters.

Now, we will see friends here I have provided the many elements here, high pressure relief valves are there from here, then high pressure relief valves are there to monitor here. You will see the when the valve will get opened. You will see here again I have shown you the some of the filters here; the this is a charge pump.

Here the check valves are their both side, what for it is which will not allow the flow from this to this. Only flow is coming from the charged pump to this way to run the piston pump or it will come from here and it will go to the other side of the piston pump. These check valves will isolate high pressure at the low pressure correct.

Many things are there here you will understand also you will see your the shuttle valve is there. The shuttle valve it is a in the middle center all ports are blocked. This will be actuated when the flow is sending this way. It will rotate the piston motor in one direction. When the direction of the piston pump is changed, when the flow is coming from here like this that time what happen this will be actuated.

That is why is the pilot lines I have shown to shift to the left or a right based on how the flow is coming.

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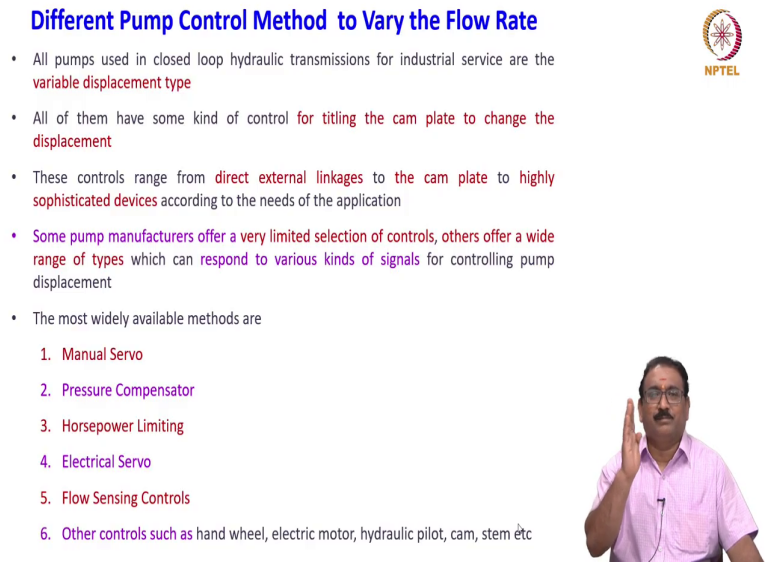

Now, as I have told you in most of the HST the pump is a variable displacement type, variable displacement, but input is constant power motor. Then anything you will vary the flow rate all these thing by changing the swash plate angle. How to change the swash plate angle? There are many methods are there. Now, we will see the different pump controlled method to vary the flow rate.

All pumps used in the closed loop hydraulic transmissions for industrial service or the variable displacement type. All of them have some kind of control for tilting the cam plate to change the displacements. These controls range from direct external linkages to the cam plate to highly sophisticated devices according to the needs of the applications; to changing alpha plus, alpha minus can be done any of the methods.

Some pump manufacturers offer a very limited selection of controls; others offer a wide range of types which can respond to various kinds of signals from controlling the pump displacement. The most widely available methods in commercial units are manual servo. 2nd one is pressure compensator, 3rd one if horsepower limiting, 4th one is electrical servo, 5th one is flow sensing controls. Also other methods are there such as hand wheel electric motor, hydraulic pilot, cam, stem, etcetera.

The whole objective is to vary the angle in case of the piston pumps. These are the commonly used methods.

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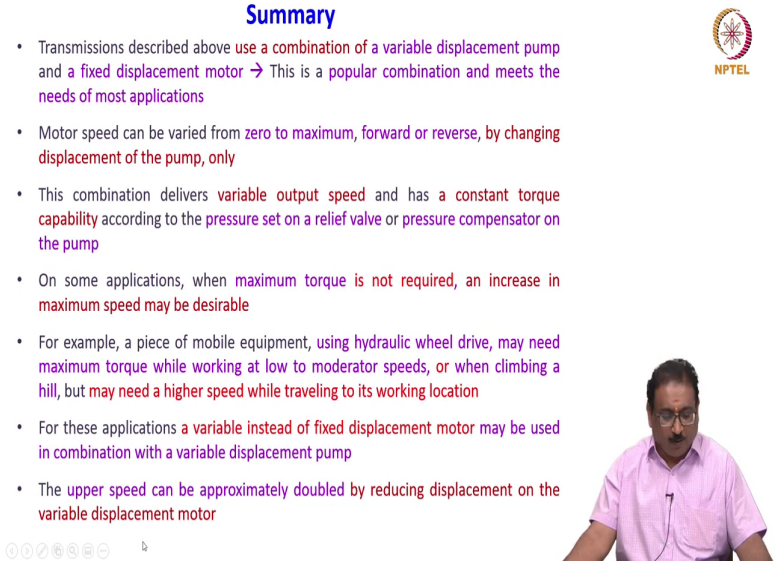

Now, let us we will see what we have discussed now. Transmissions described above use a combination of variable displacement pump, and a fixed displacement motor. It may be the

unidirectional or a bidirectional, but you will remember it is a fixed displacement. It finds a wide applications. This is the popular combination and meets the needs of most applications.

Motor speed can be varied from zero to maximum, forward or reverse, by changing the displacement of the pump only. This combination delivers variable output speed and has a constant torque capability. According to the pressure set on the relief valve or a pressure compensator on the pump.

On some applications, when the maximum torque is not required, an increase in maximum speed may be desirable. For example, a piece of mobile equipment using a hydraulic wheel drive, may need a maximum torque while working at low to moderate speeds, or when climbing a hill, but may need a higher speed while travelling to its working locations.

For these applications what is required friends a variable instead of the fixed displacement motor may be used in combination with variable displacement pump and I will understand friends. Previously I have used the variable displacement pump and a fixed displacement motor, but some applications will call for the variable displacement motor also. The upper speed can be approximately doubled by reducing the displacement on the variable displacement motors.

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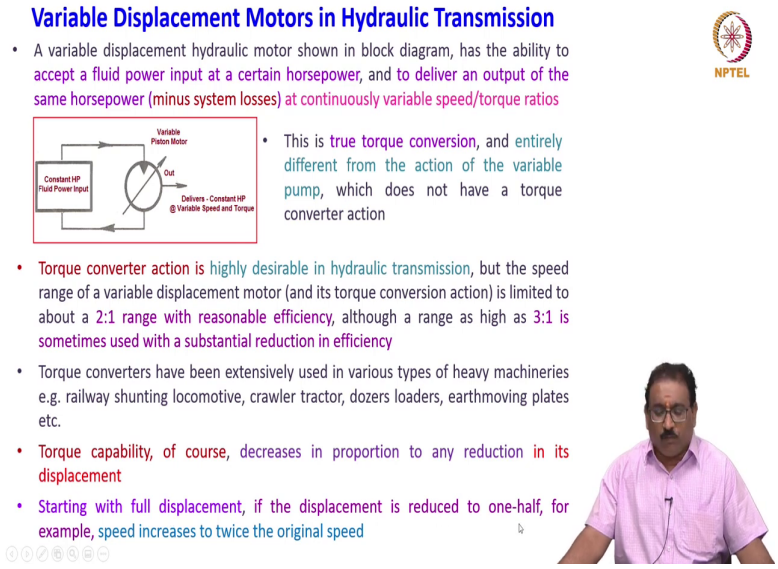

Quickly we will see some of the features of variable displacement motors in hydraulic transmissions. A variable displacement hydraulic motor shown in block diagram, has the ability to accept fluid power input at a certain horsepower, and to deliver an output of the same horsepower, maybe some system losses, at a continuously variable speed and torque ratios.

This is the true torque conversion and entirely different from the action of the variable pump, which does not have the torque conversion ability. Torque converter action is highly desirable in hydraulic transmission. But, the speed range of variable displacement motor and its torque conversion action is limited to about a 2 is to 1 range with a reasonable efficient. Although a range as high as 3 is to 1 is sometimes used with a substantial reduction inefficiency.

Torque converters have been extensively used in various types of heavy machineries, like railway shunting locomotive crawler tractor, dozer loaders, earth moving plates and many more. Torque capability of course, decreases in proportion to any reduction in it is displacement. Starting with full displacement, if the displacement is reduced to one half for example, speed increases to twice the original speed.