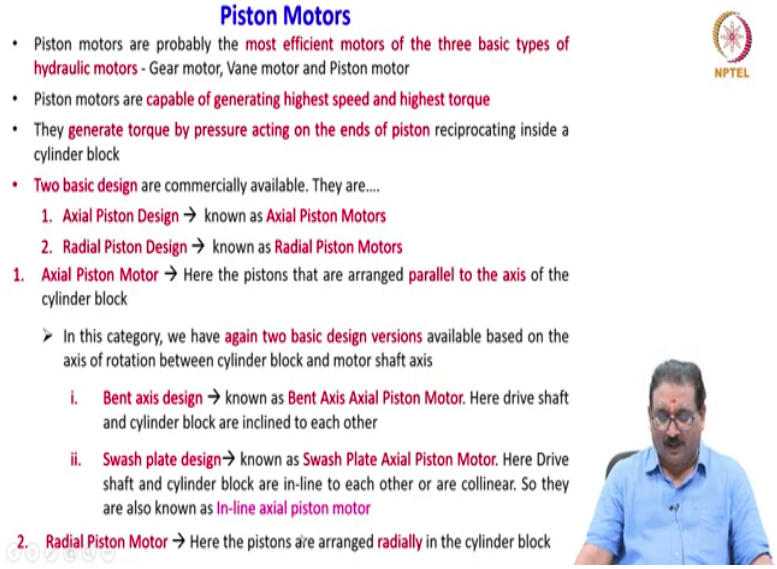
Oil Hydraulics and Pneumatics
Prof. Somashekhar S
Department of Mechanical Engineering
Indian Institute of Technology, Madras

Part 5: Construction and Operation of Piston Motors
-Bent-axis type and Swash plate type
Lecture - 49
Hydraulic Motors

(Refer Slide Time: 00:23)

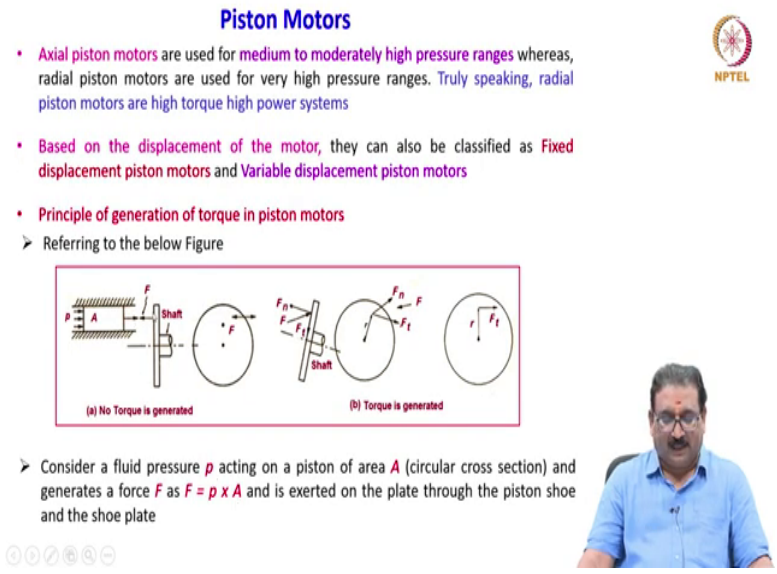


My name is Somashekhar, course faculty for this course. Now, we will move on to piston motors. Piston motors are probably the most efficient motors of the three basic types of hydraulic motors. Piston motors are capable of generating highest speed and highest torque. They generate a torque by pressure acting on the ends of the piston reciprocating in a cylinder block. Two basic designs are commercially available.

They are axial piston design known as axial piston motors; radial piston design known as radial piston motors. Axial piston motor here the pistons that are arranged parallel to the axis of the cylinder block. In this category, we have again two basic design versions available based on the axis of rotation of the cylinder block and motor shaft axis.

First category here is bent axis design known as bent axis axial piston motor. Here drive shaft axis and a cylinder block axis are inclined to each other. Second category, swash plate design known as swash plate axial piston motor. Here drive shaft and cylinder block are in-line to each other that is collinear. So, they are also known as in-line axial piston motor. In case of the radial piston motor, pistons are arranged radially in the cylinder block.

(Refer Slide Time: 02:26)



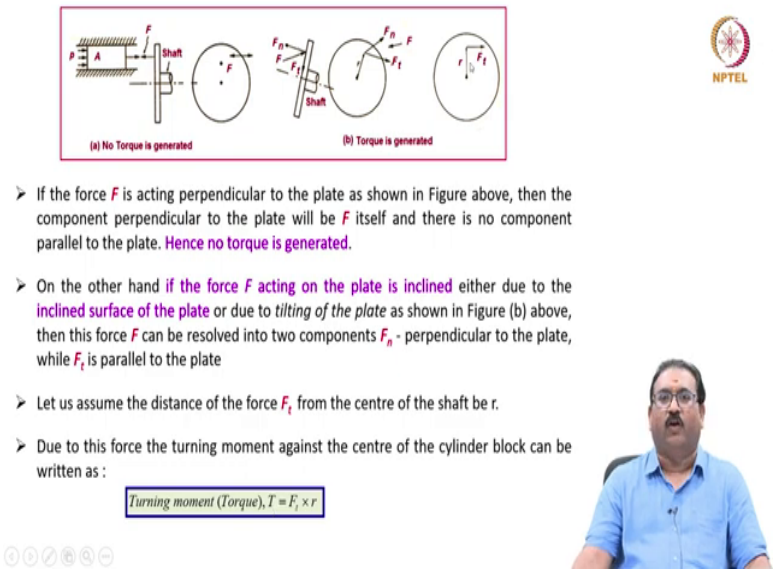
Axial piston motors are used for medium to moderately high pressure ranges, whereas, radial piston motors are used for very high pressure ranges. Truly speaking, radial piston motors are

high torque high power systems. Another category of classification generally seen are based on the displacement of the motor they are also classified as fixed displacement piston motors and a variable displacement piston motors.

Now, quickly we will see on principle of generation of torque in piston motors. As I have already told you the high pressure oil acting on the circular area of the piston which will generate the force. This force acting on the plate swash plate which will generate the torque to rotate the motor.

Now, let us we will see the what is the principle of generation of torque in the piston motors. Here you will referring to the figure below. Here I have shown you only one piston and cylinder here and this is a shaft and flange. Consider a fluid pressure p acting on the piston area A as I have told you a circular cross section and generate a force F as because F equal to p into A and is exerted on the plate through the piston shoe and the shoe plate.

(Refer Slide Time: 04:24)

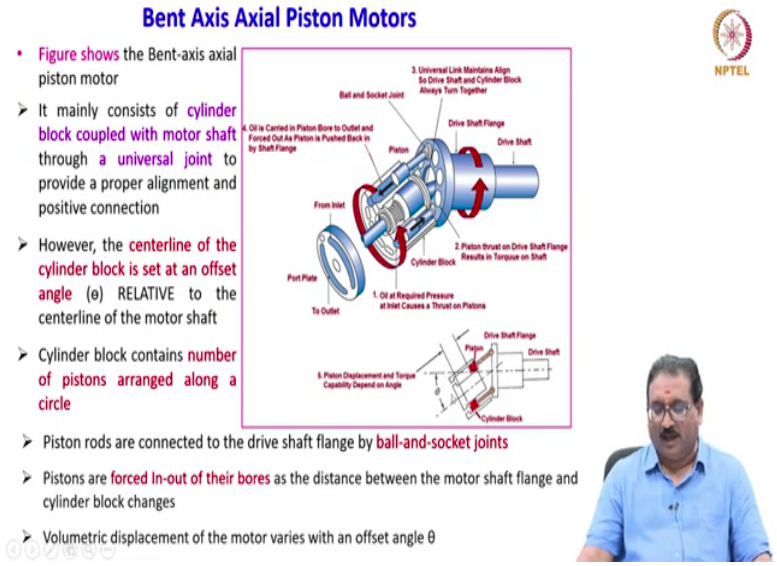


If the F is acting perpendicular to the plate as shown in the figure here, then the component perpendicular to the plate will be F itself, and there is no component parallel to the plate. Hence, no torque is generated. When it is? When the forces acting perpendicular to the flange of the shaft.

On the other hand, if the force F acts on the plate is inclined, you will see inclined, either due to the inclined surface of the plate or due to the tilting of plate as shown in figure b above, then this force F can be resolved into two components F n, perpendicular to the plate, while F t parallel to the plate.

Let us assume the distance of the force F t from the centre of the shaft is small r. Due to this force, the turning moment against the centre of the cylinder block can be written as a turning moment or a torque T equal to F t into distance r is a torque.

(Refer Slide Time: 06:02)



Now, we will see the one by one how the constructional features and generation of torque in each type of motor. First one is bent-axis axial piston motor. The name itself tells us that the cylinder block and the motor shaft, here what I am written here a drive shaft inclined to each other.

It mainly consists of the cylinder block, this is you will see, this is a cylinder block it is coupled with the mortar shaft through the universal joint to provide a proper alignment and a

positive connection between the driveshaft and the cylinder block. However, the centre line of the cylinder block is set at an offset angle theta, there is a theta here.

Here you will see your theta relative to the centre line of the motor shaft. Please see here friends there are various parts are shown here. This is a cylinder block in which the various pistons are reciprocating in and out based on the pressure acting on the surface area.

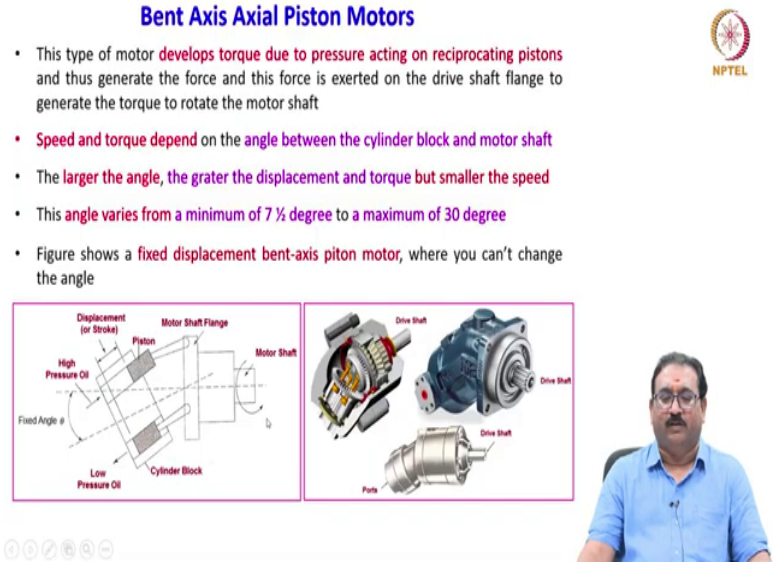
Then you will see here the pistons connected to the driveshaft flange using the universal link. Meaning here you will see here the piston rod is connected to the drive flange through the ball and socket joint. These are all the ball and socket joints. Other end the port plate – kidney shaped port plate from the inlet where the pump pressure is acting over it and this is a outlet which is connected to the tank.

Now, cylinder block contains a number of pistons arranged along a circle. Piston rods are connected to the drive shaft flange by ball and socket joints. Pistons are forced in and out of their bores as the distance between the motor shaft flange and the cylinder block changes. Volumetric displacement of the motor varies with an offset angle theta. You will see here there is an offset angle between the cylinder block and the motor shaft.

See here operation I am written here; the important five points I am written here. You will see here the oil pressure at required pressure at the inlet causes the thrust on the piston. Piston thrust on the drive shaft flange results in torque on shaft. Here you will see the universal link maintains align, so drive shaft and a cylinder block always turn together.

Here this is a ball and socket joint as I have told you. Here you will see oil is carried in a piston bore to outlet and forced out as the piston is pushed back in by shaft flange. Here you will see the piston displacement and a torque capability depends on the angle theta.

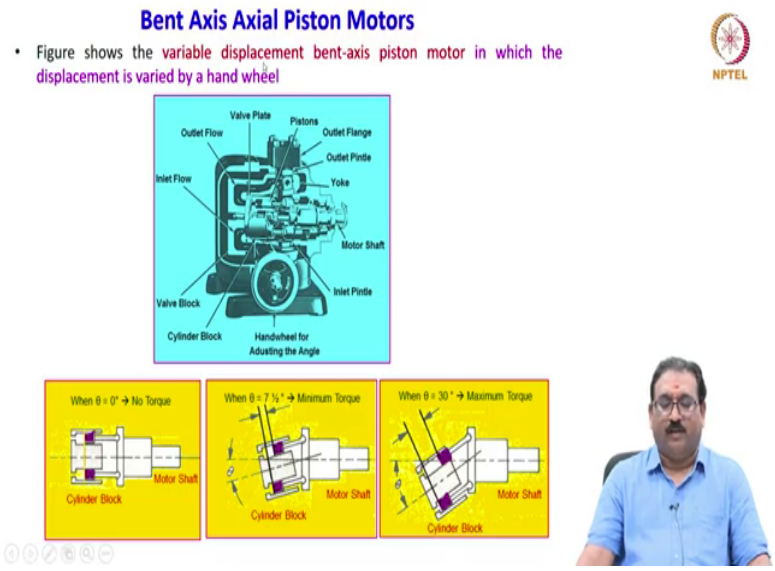
(Refer Slide Time: 10:06)



This type of motor develops a torque due to pressure acting on reciprocating pistons and thus generate the force and this force is exerted on the drive shaft flange to generate the torque to rotate the motor shaft. Speed and torque depend on the angle between the cylinder block and motor shaft.

The larger the angle, the greater the displacement and a torque, but smaller the speed. This angle varies from a minimum of 7 and a half degree to a maximum of 30 degree. Here figure shows a fixed displacement bent-axis piston motor, where you cannot change the angle between the cylinder block and driveshaft. It is fixed that is why it is called a fixed displacement bent-axis axial piston motors.

(Refer Slide Time: 11:20)

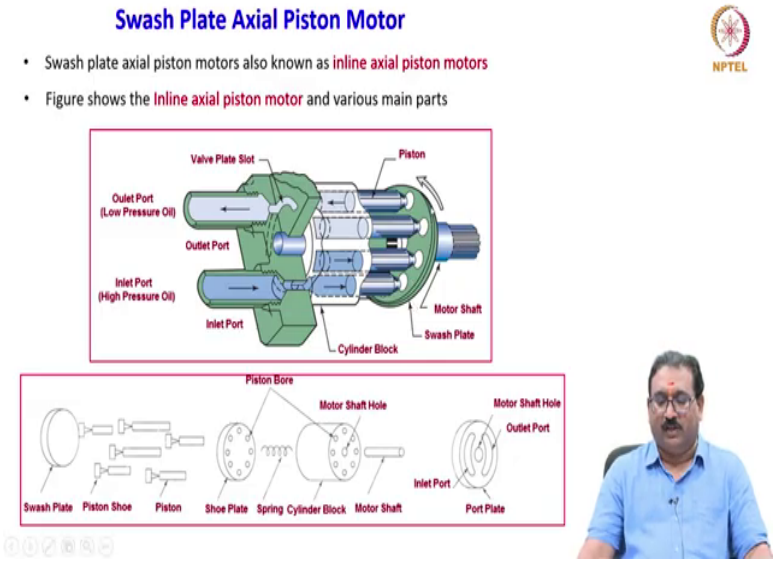


Here you will see the figure shows the variable displacement bent-axis piston motor in which the displacement is varied by a hand wheel, the hand wheel is provided and then yoke is there, correct. You will rotate the hand wheel for adjusting the theta. When theta is 0, meaning when the cylinder block is aligned with the motor shaft, no stroke; pistons are on the same line that is why there is no torque.

When theta is for example, minimum 7 and a half degree, you will see the angle here which will produce the minimum torque. If you will rotate to 30 degree maximum, that time you will get the maximum torque because of this angle. Stroke also you will please observe. This arrangement is provided in the variable displacement bent-axis axial piston motors by providing here in this figure the hand wheel.

Hand wheel is to adjust the distance between the cylinder block at the drive shaft by rotating.

(Refer Slide Time: 12:44)



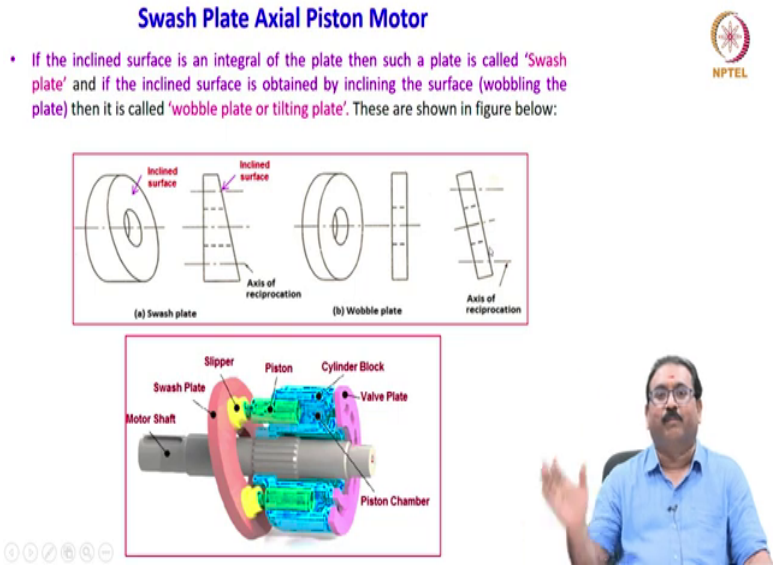
Now, we will move onto the swash plate axial piston motor. Swash plate axial piston motors are also known as inline axial piston motors. See here the figure shows the inline axial piston motor at a various parts. You will see here friends the inlet port is there, meaning high pressure oil from the pump and control elements will enter here. These are the pistons.

And you will see the pistons are reciprocating in line with the cylinder block. But how it is? You will see here, there is a swash plate which may be a fixed meaning it is the swash plate angle is adjustable type, in the variable type motors. In fixed motor, the swash plate angle is fixed. Then this is a motor shaft. The direction of rotation is shown here.

You will see here. What are the important parts are there friends here? After rotating the shaft the oil will exit from the outlet port to the tank, there is a low pressure oil. Now, we will see very important parts here a swash plate. Here this is a swash plate. Then piston with piston shoes, piston with piston shoe lies on the swash plate.

Then shoe plate, then it is a spring. Then cylinder block which has a piston bolts in which you how to insert the pistons. Then you will see motor shaft. Then last important part is a port plate which has a inlet port and the outlet port. They are in the kidney shaped port openings.

(Refer Slide Time: 14:51)

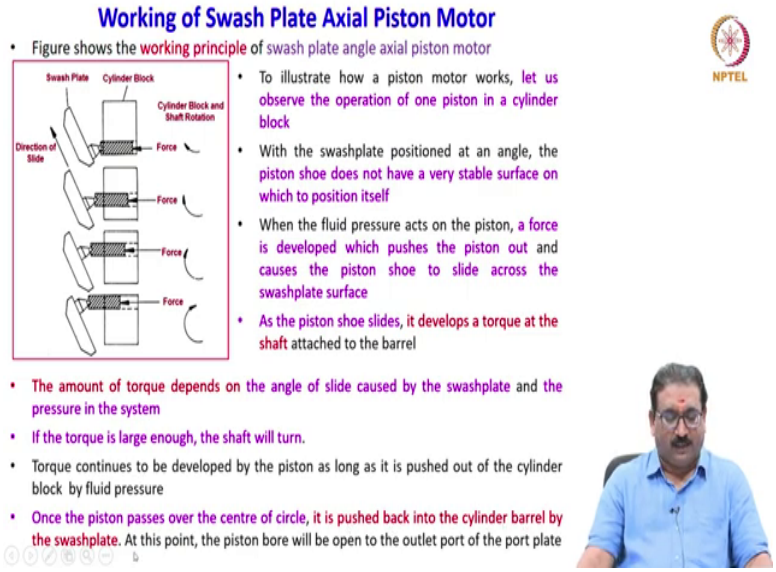


If the inclined surface is an integral of the plate, then such a plate is called a swash plate. And if the inclined surface is obtained by inclining the surface meaning by wobbling the plate that

arrangement is also provided, then it is called a wobble plate or a tilting plate. These are shown in the figure below here.

You will see here if the inclined surface is fixed one – you cannot change here then this is a swash plate. But you will see here one more I have shown wobble plate I have shown here, here axis of reciprocation you will see. Meaning you have to adjust like this or like this. This is a wobble plate design.

(Refer Slide Time: 15:46)



Now, we will see the working of swash plate axial piston motor. In this sketch, you will see here friends I have shown the swash plate and only one piston in the cylinder block. To illustrate how the piston motor work, let us observe the operation of one piston in a cylinder block. With the swash plate positioned at an angle, the piston shoe does not have a very stable surface on which to positions itself.

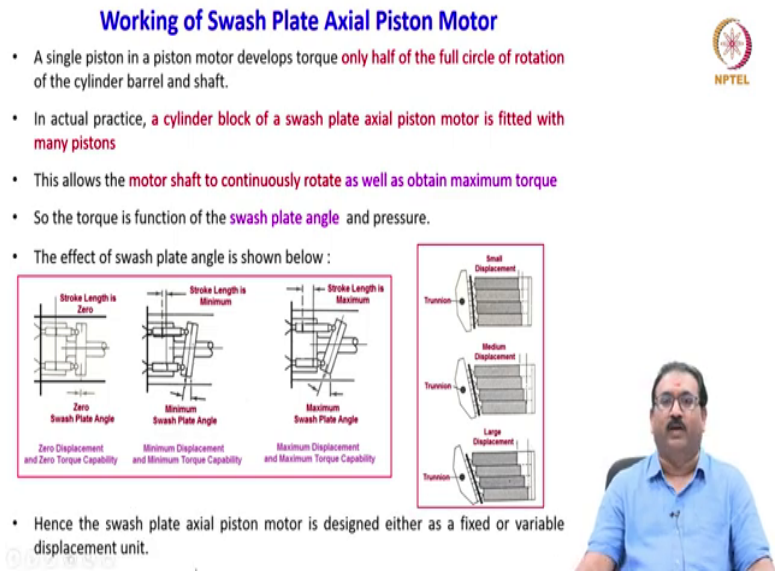
When the fluid pressure acts on the piston, the force is developed, as I have told you F equal to p into A which pushes the piston out see here piston out and causes the piston shoe to slide across the swash plate. Meaning it is rotating, you will see here it will rotate – cylinder block. As the piston shoe slides, it develops a torque at the shaft attached to the barrel.

The amount of torque depends on the angle of slide caused by the swash plate and the pressure in the system. If the torque is large enough, the shaft will turn. Torque continues to be developed by the piston as long as it is pushed out of the cylinder block by a fluid pressure.

You will see here the angle of slide and rotation how it is. The fluid pressure pushes, pushes, pushes, and slides. You see here, now it is coming up, down, slide, slides, up, the piston will come, but only is the one piston. But in reality, there are various types of pistons are there moving.

Once the piston passes over the centre of the circle, it is pushed back into the cylinder barrel by the swash plate. At this point, the piston bore will be open to the outlet port of the port plate.

(Refer Slide Time: 18:25)



A single piston in a piston motor develops a torque only half of the full circle rotation of the cylinder barrel and a shaft. In actual practice, a cylinder block of a swash plate axial piston motor is fitted with the many pistons. Generally for the smooth operation, they are odd in numbers; 7, 9, 11 like this which will provides the pressure is meaning smooth pulsation.

Not the very pressure pulsation is very less in case of the odd number of pistons. This allows the motor shaft to continuous rotate as well as to obtain the maximum torque. So, the torque is a function of the swash plate angle and a pressure. You will see here I have shown the effect of swash plate angle on the torque generation. You will see here.

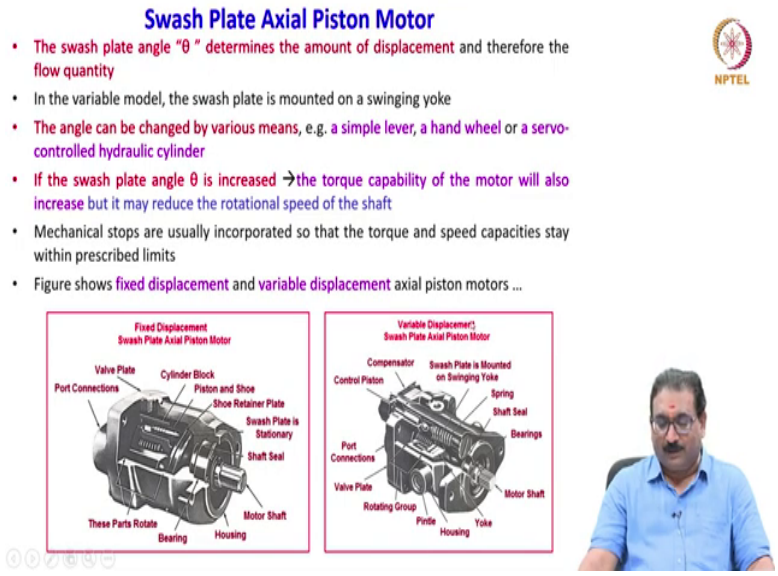
When the swash plate here swash plate inline, now we will see there is zero stroke, stroke length is 0 meaning the pistons only will rotate like this; no suction, no discharge that is a zero swash plate angle which will results in zero displacement and zero torque capability.

When you will tilt this swash plate by minimum swash plate angle as I have shown here, which will results in the, you will observe the stroke length is minimum, which results in minimum displacement and minimum torque capability. When still further you will rotate the swash plate, you will see the maximum swash plate angle results in maximum displacement and a maximum torque capability.

Here I have shown you only two piston. If more number of piston, you will see here from here to here, the small displacement with respect to the swash plate. Swash plate is putting on the trunnion which can be a rotatable type. Here you will see swash plate angle is medium, you will see the stroke here from the here to last.

Similarly, we will trunnion again swash plate is inclined more that time large displacement, meaning there is a provision is made in a variable displacement to rotate the swash plate to the desired angle. Hence, the swash plate axial piston motor is designed either as a fixed or a variable displacement unit.

(Refer Slide Time: 21:25)



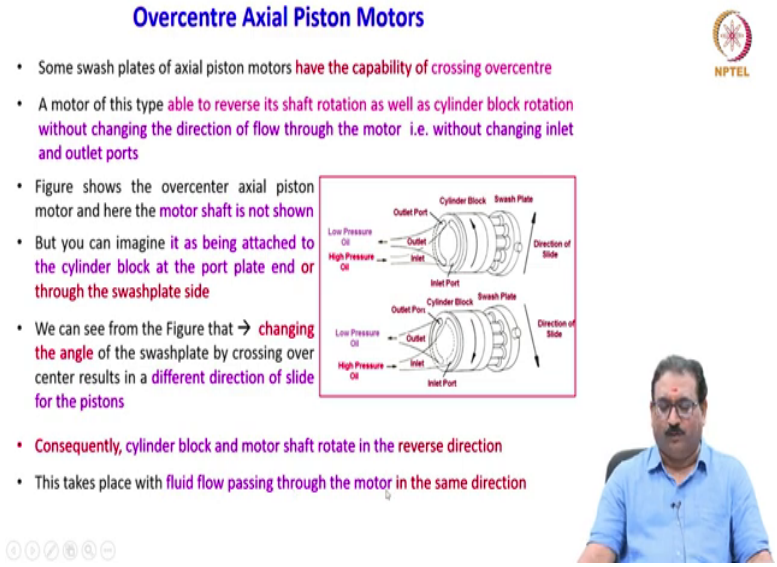
The swash plate angle theta determines the amount of displacement and therefore, the quantity of fluid. In the variable model, the swash plate is mounted on a swinging yoke. The angle can be changed by the various means, that is use a simple lever, or a hand wheel, or a servo controlled hydraulic cylinders.

If the swash plate angle theta is increased, the torque capability of the motor will increase but it may reduce the rotational speed of the shaft. Please understand this. Mechanical stops are usually incorporated so that the torque and speed capacities stay within the prescribed limits.

Figure shows the fixed displacement and a variable displacement axial piston motors. You will see here in this case first one fixed displacement swash plate axial piston motor, thus this is fixed then similarly all other parts I have shown here. In a variable displacement thing, the

swash plate is mounted on the swinging yoke which can be adjusted through the hand wheel, or a lever, or a servo controls cylinders. You can vary this.

(Refer Slide Time: 22:56)



Then some of the cases, the over centre axial piston motors serves the many purpose. What are those? We will see now. Some swash plates of the axial piston motors have the capability of crossing over centre. A motor of this type able to reverse its shaft rotation as well as a cylinder block rotation without changing the direction of flow through the motor that is without changing the fluid flow in the inlet and outlet ports.

How it is? You will see here. Figure shows the over centre axial piston motor and here the motor shaft is I have not shown here as because, but you can imagine it is being attached to the cylinder block at the port end or through the swash plate side. We can seen from the

figure that here you will see friends the direction of the swash plate you will see here in the first, and see the direction of rotation in the second case it is like this.

The inlet, outlet, I am not changing. I am changing the rotation of the swash plate like this or a like this. This is a crossing over centre design. Here you will see changing the angle of swash plate by crossing over centre results in different direction of slide for the piston.

You will see here, in this design, here like this, the slide is direction of slide is like this when they will move, cylinder block will rotate. But in the other case, you will see the sliding direction is this way. You see the sketch here, but you will see the inlet outlet whatever it is there, I am not changing, inlet pressure is here only, outlet pressure is here only.

Inlet is connected to the pump through various valves meaning high pressure oil, and outlet is connected to the tank. After rotating it is a low pressure oil only, but here I am not changing. What I am changing? I am changing the direction of rotation of the swash plate.

Consequently, the cylinder block and motor shaft rotate in the reverse direction without changing the direction that is a beauty of the over centre axial piston motors. This takes place with fluid flow passing through the motor in the same direction.