Oil Hydraulics and Pneumatics
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Part 2: Vane Pump, Pumping Theory, Construction and Operation of Unbalanced Vane Pump, Vane loading and solutions, Different Vanes
Lecture - 18
Vane Pumps

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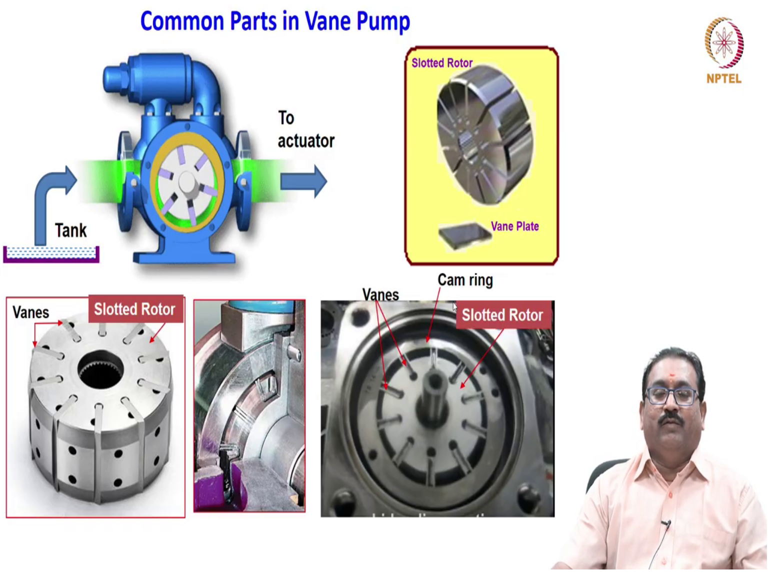

My name is Somashekhar, course faculty for this course. This figure will show you some of the main parts in the Vane Pumps. Slotted rotor and a vane plate; this vane plate is a rectangular plate which will slides in the slots of the rotor either freely or through the spring. For better understanding, I shown you some of the photographic view of the pump.

Here you will see the slotted rotor and a vanes are inserted here we will see the vanes rectangular vane plates. Here also you will see in assembly rotor and vanes are here. Here you will see these are the vanes this is a rotor connected to the shaft here of the prime mover and one more very important part what I have shown you the cam ring.

These are the main elements in the vane pump irrespective of whether it is a balanced vane pump or variable type of pumps. What are the three important parts? Slotted rotor, vanes and cam ring. These are the important parts in the vane pump.

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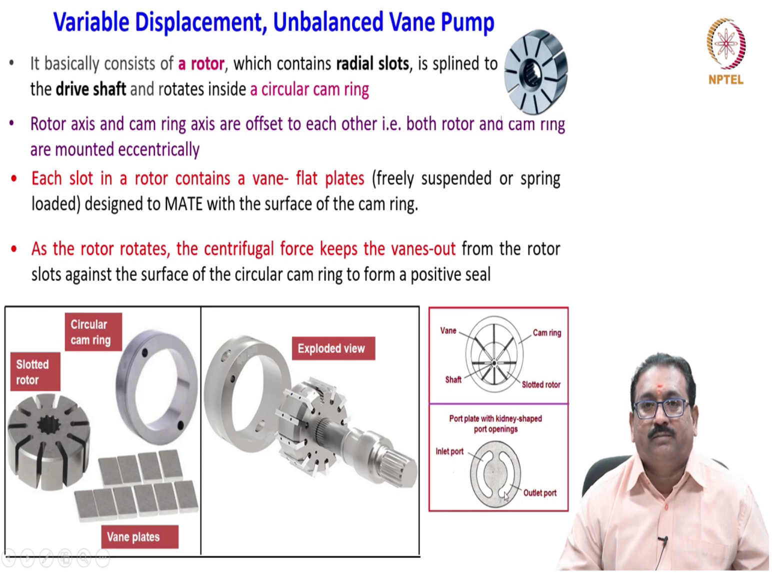

Let us we will see one by one. Variable displacement, unbalanced vane pump it is what we are discussing now. It basically consists of a rotor which contains a radial slots is flying to the drive shaft and rotate inside a cam ring.

This will show the various parts here – slotted rotor, circular cam ring and a vane plates. These vane plates are inserted in the rotor you will see here. Vane plates how they are freely suspended then rotor is connected to the shaft this is a cam ring. Also you will see here some of the schematic diagram I have drawn. This one is cam ring, this is a rotor and these are the vanes.

Now, we will see here friends, in this figure the rotor axis and a cam ring axis are offset to each other, that is, both rotor and cam ring are mounted eccentrically. You will see this axis is a cam ring axis; this is a rotor axis both are offset to each other.

Each slot each slot in a rotor contains a vane which who which are flat plates as I have told you freely suspended or a spring loaded. They designed to mate with the surface of the cam ring. During the operation they will mate with the surface of the cam ring.

As the rotor rotates, the centrifugal force keeps the vanes out from the rotors slot against the surface of the circular cam ring to form the positive seal. You will see here when the rotor starts rotating the vanes will thrown out and they will mate with the surface of the cam ring.

What for it is? They will seals, meaning oil will carried in the pockets from the suction to the discharge. Then vanes when they will reciprocate, how it is? You will see here the port plates port plate with a kidney shaped port openings, this is a inlet port and a outlet port.

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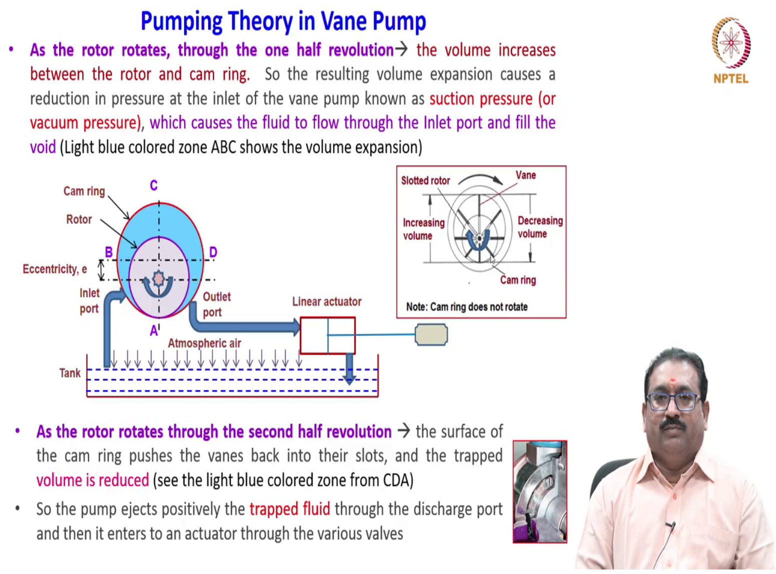

Now, we will see the pumping theory in a vane pump how the fluid is transport from the tank to the actuator side. How it is? Let us we will see.

As we know as the rotor rotates through one half revolution, what happens? The volume increases between the rotor and the cam ring. So, the resulting volume expansion causes a reduction in pressure at the inlet of the vane pump known as the suction pressure or a vacuum pressure which causes the fluid to flow through the inlet port and fill the void out.

You will see friends here the schematic diagram this is a rotor, rotor axis, cam ring, cam ring axis. For better understanding of the pumping theory I have not shown the vane. Here you will see here when the rotor rotates the increasing volume you will observe friends here A, B, C this area you will see the volume increases in the half revolution of the rotor.

This increasing volume creates a partial vacuum at the inlet beginning. Once the fluid is clashed fluid is transport to the other side on the another half revolution. What happened? We will see another half revolution, this area you will see decreasing.

So, as the rotor rotates through second half of the revolution the surface of the cam ring pushes the vanes back into their slot, and the trapped volume is reduced. See the light blue colored line what I have marked here when the rotor rotates another half revolution this volume decreases. So, what happens? The pump ejects positively the trapped fluid through the discharge port and then it enters the actuator through the various valves.

Please see here friends, the pumping theory is very very important which will shows us that the increasing volume and decreasing volume is very very essential. If this increasing volume and decreasing volume will not ensured, then pump will not sends the any flow that is very important. You will see here when it will rotate I have marked here the increasing volume, then it will rotate another half it is a decreasing volume.

So in one word when the rotor rotates half revolution volume increases and the vanes thrown out which will mate with the cam surface for the positive sealing and the oil will carried in the void to that charge side. During the discharge what is very important another half revolution of the rotor pushes the fluid out of the discharge port.

There is increasing volume and a decreasing volume is a very very important in the pumping theory which is ensured here what I have shown you.

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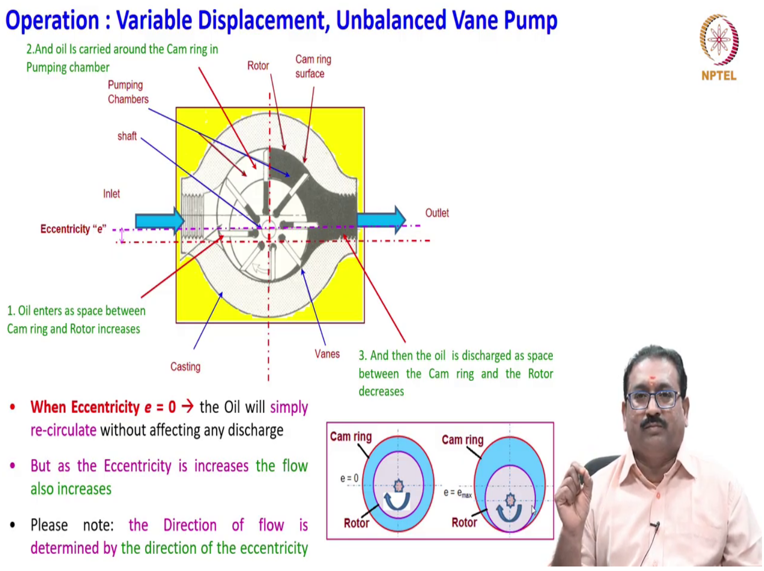

Let us quickly I will show you here same thing it is. Here you will see friends the increasing volume that is why oil enters in this region. Then what happens? Oil is carried around the cam ring and pumping chambers these are the see here what I have marked here, also you will see friends the vane will seals positive seal. Vane will thrown out and it will come to the surface of the cam ring, then oil will be carried.

Then here the volume decreases, what happened? Then the fluid is discharged from the port, the inlet port outlet port. When this eccentricity what I have shown here is 0, then what happened friends? No increasing volume, then only it will re-circulates no discharge you will get. That is why when eccentricity is 0 the oil will simply re-circulate without affecting any discharge.

But, as the eccentricity is increased thus the flow also increases. Please note the direction of flow is determined by the direction of eccentricity I will explain this thing in the next slide. You will see here friends, when the rotor axis and a cam ring axis coincides each other meaning 0 eccentricity.

No flow because no increasing volume or no decreasing volume, all volumes are same. But, we will see here when the I am giving the eccentricity here I view maximum eccentricity e max that I will see the one half the volume increases, another half rotation volume decreases. Meaning always there is an eccentricity between the cam ring and the rotor axis meaning there is a provision to make this e variable in the variable displacement pump. In the fixed displacement pump e is fixed.

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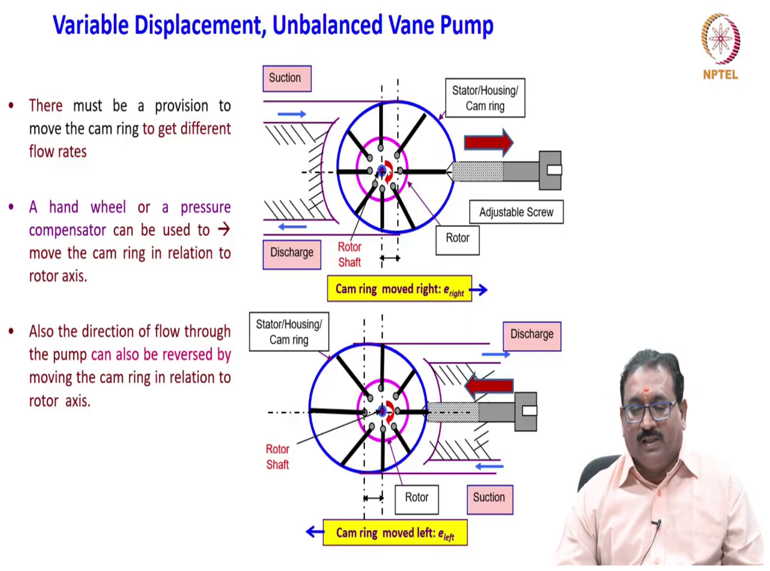

Now, let us we will see there must be the provision to move the cam ring to get the different flow rates. A hand wheel or a pressure compensator can be used to move the cam ring in relation to the rotor axis. As I have told you the direction of flow through the pump can also be reversed by moving the cam ring in relation to the rotor axis.

I will show you the simple sketch here. See friends here; please see the suction port and discharge port, and that direction of movement of the cam ring. Here a cam ring I moved from the center of the rotor to the right side, then what happened? When it will rotate the volume increases that is why it is a suction then it will carried and discharged to the outlet.

But, if you move the cam ring this to the left side you will see now I moved the left side that time what happened? When the rotor will rotate this volume we will see half it will goes on increasing that is why suction is here and discharge is here. Please note friends, if e increases flow rate increases also which direction you are moving the cam ring will matters to decide which is the suction side and which is the discharge side which is a suction side and which is a discharge side.

The moment of the cam ring is very very important are the two things if e is increasing flow rate increasing and whether it is a you are moving the here in this figure you are moving the right side suction is here as because volume increases in this direction. If you move here, the volume increases in this direction when the rotor rotates.

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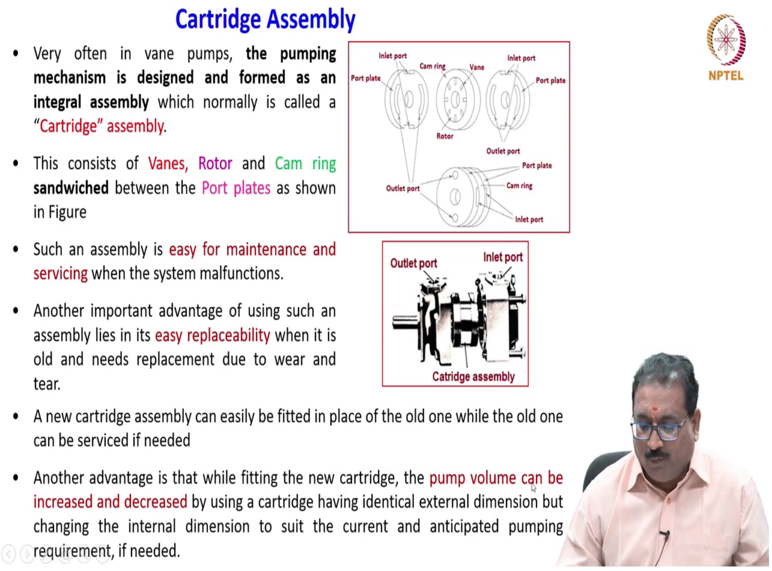

Now, we will see friends in the vane pump these are the three important parameters, what is that? The cam ring, slotted rotor and the vanes; slotted rotor and the cam ring are offset to each other to get the flow.

Then you will see what is this cartridge assembly. Very often in a vane pumps the pumping mechanism is designed and formed as an integral assembly which normally is called a cartridge assembly. This consists of vanes, rotor and a cam ring sandwiched between the port plates as shown in the figure here.

You will see here rotor, vanes, cam ring and these are the kidney shaped port openings, port plates. You will see here the whole assembly cartridge assembly is like this. You will also see here cartridge assembly port plates integral all in one.

Such an assembly is easy for maintenance and servicing when the system malfunctions. Another important advantage of using such an assembly lies in it is easy replaceability when it is old and needs a replacement due to wear and tear. A new cartridge assembly can easily be fitted in place of the old ones when the old ones can be served for servicing if needed.

Another advantage is that while fitting the new cartridge, the pump volume can be increased and decreased by using the cartridge having identical external dimension, but changing the internal dimension to suit the current and anticipated pumping requirement if needed. Another advantage when you are using the cartridge assembly.

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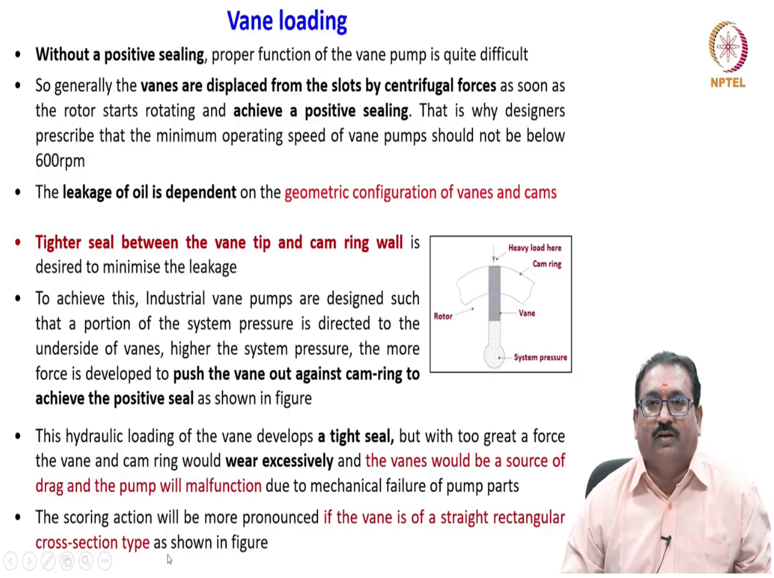

Now, we will see the vane loading. The vane loading is very very important because when the vanes will thrown out we required the positive sealing from the vane to the cam ring surfaces. Without the positive sealing, proper functioning of the vane pump is difficult task.

So, generally the vanes are displaced from the slots by the centrifugal force as soon as the rotor starts rotating and achieves a positive sealing. That is why designer prescribes that the minimum operating speed of the vane pumps should not be below 600 rpm. The leakage of oil is dependent on the geometric configuration of the vanes and a cams. Tighter seal between the vane tip and a cam ring wall is desired to minimize the leakage.

So, to achieve this industrial vane pumps are designed such that a portion of the system pressure is directed to the underside of the vanes, higher the system pressure more force is developed to push the vane out of the cam ring to achieve the positive sealing as shown in the figure here.

What they will do friends? When the as I have told you these vanes are freely suspended in the slot to make the positive sealing, what they will do? At the underside they will use the small portion of the system pressure to push the vane to make the seal perfect seal between the vanes and the cam ring, that is one important things. You will see here system pressure will push here and make the seal here positive seal.

This hydraulic loading meaning I am loading the vane develops a tighter seal, but with two great force between the vane and cam ring would wear excessively and the vanes would be a source of drag and the pump will malfunction due to the mechanical failure of the pump parts. The scoring action will be more pronounced if the vanes is of the straight rectangular cross-section as shown in the figure here.

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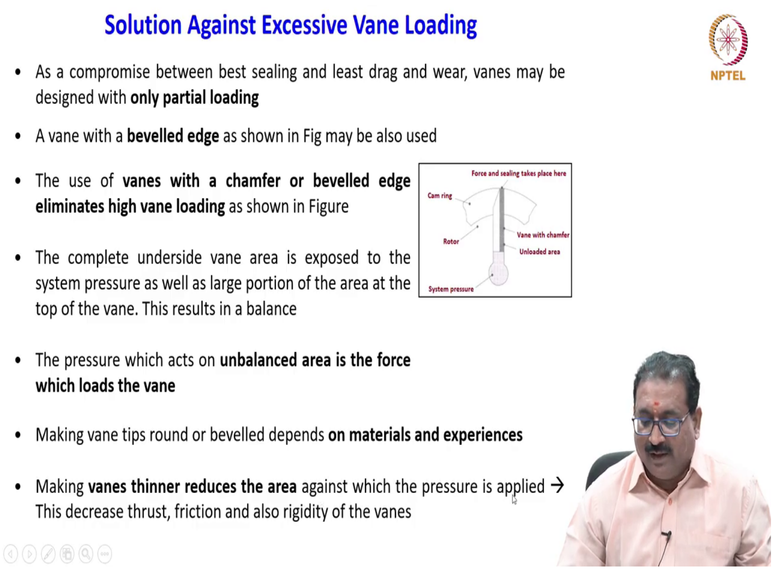

How to work on this excessive loading? As a compromise between the best sealing and the least drag and wear, vanes maybe designed with only partial loading. How to do this? A vane with a bevelled edge as shown in the figure may also be used you see here bevelled edge. Meaning you will see here hydraulic pressure available; meaning the force and sealing takes place here previously larger area.

The use of vanes with a chamfer or a bevelled edge eliminates high vane loading. The complete underside vane area is exposed to the system pressure as well as the large portion of the area at the top of the vane. This results in a balance. The pressure which acts on unbalanced area is the force which loads the vane.

Making the vane tips round or bevelled depending on the materials and a experience. Making vanes thinner reduces the area against which the pressure is applied. This decreases thrust, friction and also rigidity of the vanes.

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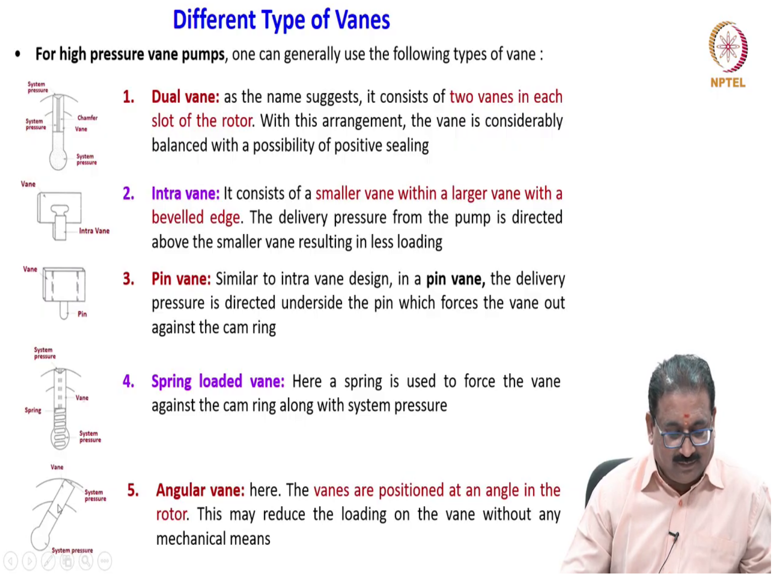

Now, we will see quickly the different types of vanes are designed to make the vanes during the operation for the positive sealing. Let us we will see. For high pressure vane pumps one can generally use the following types of vane. You will see one a dual vane, the figure is shown here a dual vane.

What is dual vane? As the name suggests it consists of two vanes in each slot of the rotor. With this arrangement the vane is considerably balanced with a possibility of positive sealing see here the system pressure what we have sending here it is available here. The two vanes in the each slots.

Next one is a intra vane, we will see the intra vane. What is this? It consists of a smaller vane within a larger vane with a bevelled edge with a bevelled edge. The delivery pressure from the pump is directed above the smaller vane resulting in less loading.

Then, pin vane. What is this pin vane? Similar to the intra vane design, in a pin vane, the delivery pressure is directed underside of the pin which forces the vane out against the cam ring surface. Or you may use the spring loaded vanes also as I have told you. Here a spring is used to force the vane against cam ring along with the system pressure you will see here.

They will fit the spring and a vane and also they will use the system pressure another one is angular vane. Here the vanes are positioned at an angle in the rotor. You see here. This may reduces the loading of on the vane without any mechanical means.

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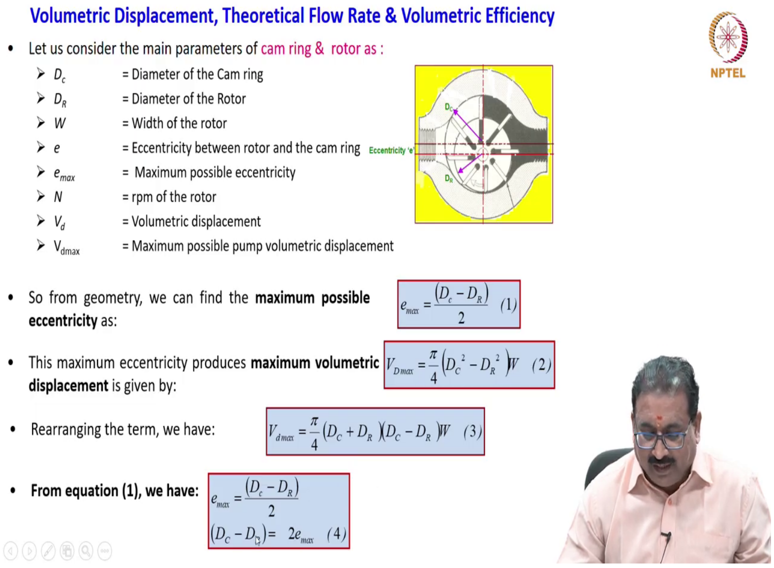

Now, quickly we will see how to arrive the volumetric displacement, theoretical flow rate and a volumetric efficiency in case of the vane pump if we know the geometrical future of the vane pump.

Now, let us consider the main parameter here the cam ring. I am seeing you is the cam ring and the rotor. D C what I am marked here D C is a the diameter of the cam, ring D R is a diameter of the rotor, W is the width of the rotor, e is a eccentricity between the rotor and the cam ring e max is maximum possible eccentricity, N is rpm of the rotor V d is volumetric displacement. V d max is maximum possible pump displacement.

So, from the geometry whatever the parameter I assumed here, we can find the maximum possible eccentricity. e max equal to D c minus D R by 2. This maximum eccentricity produces a maximum volumetric displacement which is given by pi by 4 D C square minus D R square into width of the vane width of the rotor.

Now, what we will do? Rearranging the term we have pi by 4, I am separating these into two terms – D C plus D R and D C minus D R into W, then from this equation then what is D C minus the D R? D C minus D R equals to 2 e x, then I am substituting this D C minus D R here in this equation.

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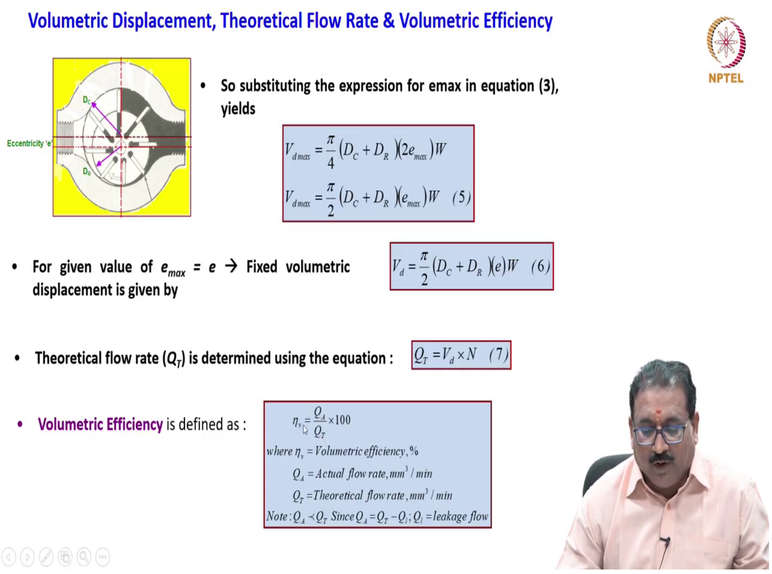

Substituting the expression here I, then what is the V d max? V d max equal 2 1 za are and 2 2 za are meaning pi by 2 D C plus D R into e max into W. For the fixed displacement pump e max is constant, correct? Then it is given by pi by 2 D C plus D R into e whatever the eccentricity into W.

Theoretical flow rate Q T is determined using the expression V d into N because already we know V d how to calculate. Once we know this the actual flow rate we are calculating using the volumetric displacement volumetric efficiency because you will see here the theoretical flow rate depending upon V d into N substitute here Q A equal to volumetric efficiency into Q T.