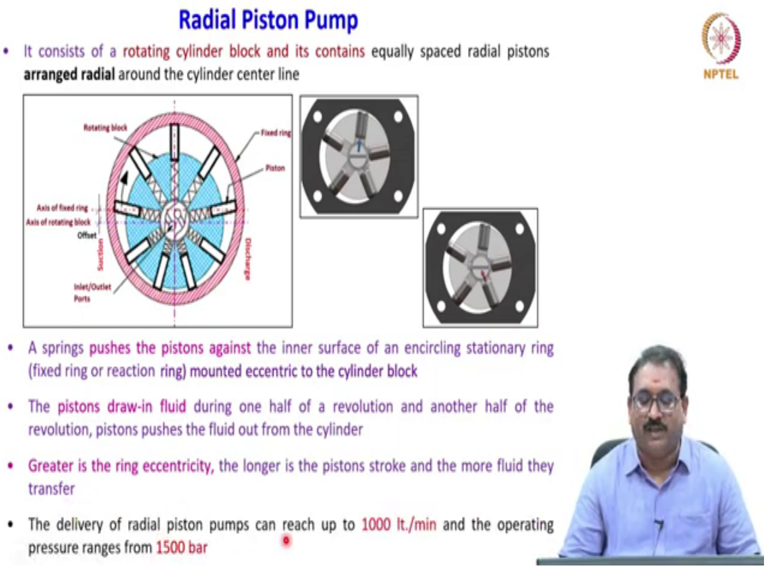
Oil Hydraulics and Pneumatics
Prof. Somashekhar S
Department of Mechanical Engineering
Indian Institute of Technology, Madras

Part 3: Radial Piston Pumps –Construction and Operation, Pump failure and Cavitations, Important Parameters while selecting Pump, Numerical
Lecture - 22
Piston Pumps

(Refer Slide Time: 00:24)



My name is Somashekhar, course faculty for this course. Now, next category is a Radial Piston Pump. You will see friends here how the pistons now, the pistons are inserted radially in the cylinder block. Then, you will see here please understand the figure here friends, this is a rotating block cylinder block middle 1 which has a radial slots are there. In the radial slot through the spring, what I did I inserted the pistons. The pistons are in line with the, what it is the fixed ring.

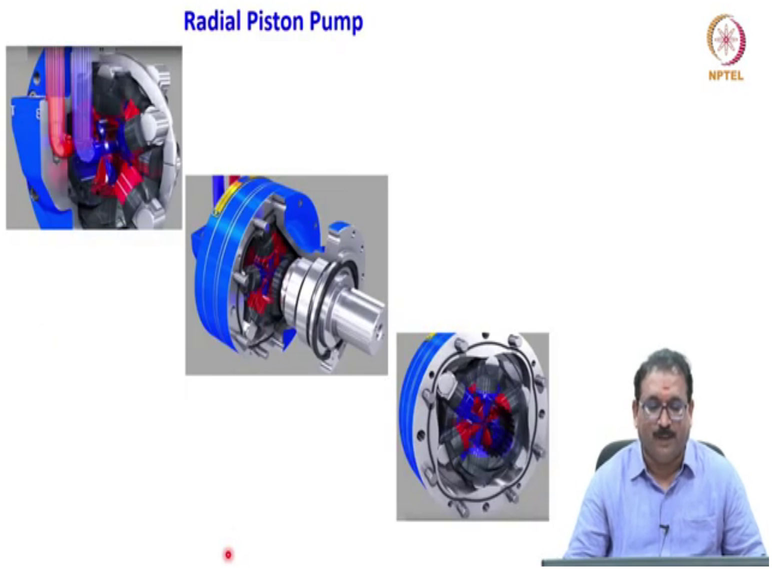
Then, you will please understand this friends, axis of the fixed ring, fixed ring is a outer one where the pistons always in contact during the rotations and axis of the rotating block or offset. Also in load inlet and outlet ports are at the middle you will see here. When it will rotates, what happens? During the half revolution what happen? Pistons will come out.

Come out means what happens? Oil will be sucked in this half. Then, when it will rotate in another half pistons will if a pushed in, what happens? During pushing, discharge will takes place. Please note here inlet and outlet ports are here middle. Same figures I have shown here. Always there is an offset between the axis of the fixed ring and axis of the rotating cylinder block.

Quickly we will see the construction, it consists of a rotating cylinder block here and it contains a, equally spaced radial pistons arranged radially around the cylinder center, you will see. A spring pushes the piston against the inner surface of the encircling stationary ring, fixed ring I am writing know, encircling stationary ring mounted eccentrics to the cylinder block.

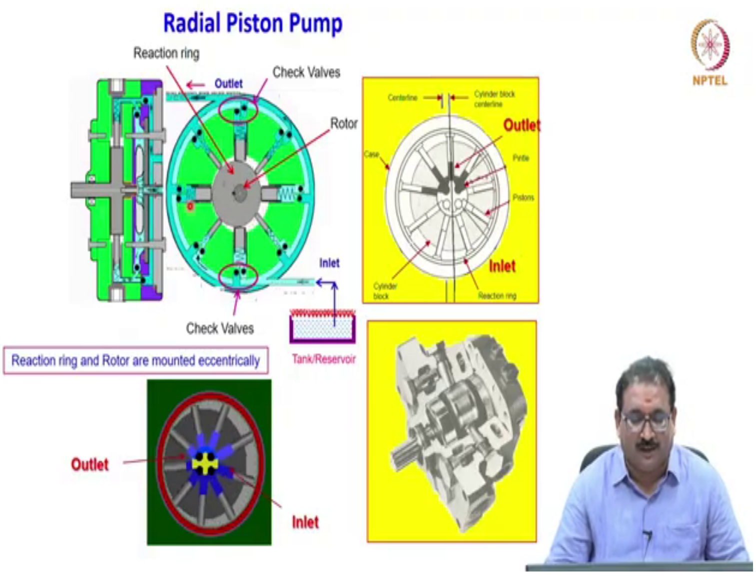
The piston draws in fluid during one half of the revolution and another half of the revolution pistons pushes the fluid out of the piston. Greater the ring eccentricity the longer is the piston stroke and the more fluid they transfer. Please note, the delivery of radial piston pumps can reach up to 1000 liters per minute and the operating pressure ranges from 1500 bar.

(Refer Slide Time: 03:05)



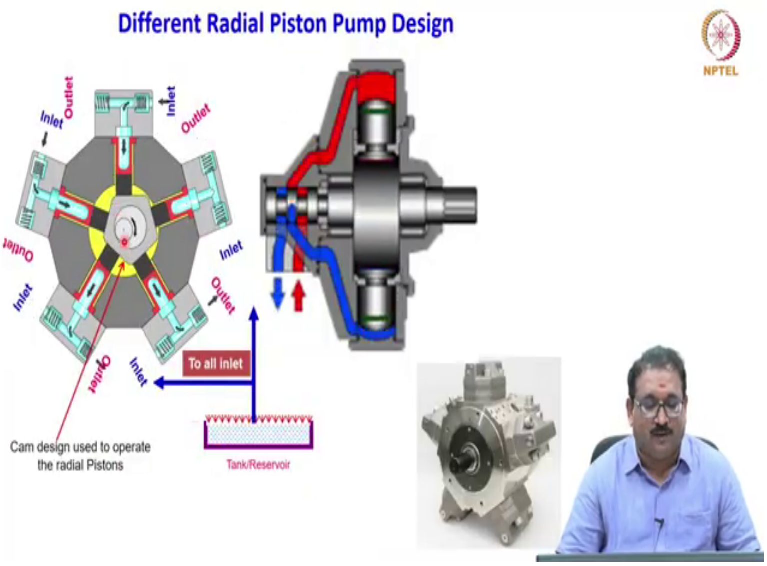
You see the better understanding, it is I have shown the pistons here you will see the pistons, radially they are arranged. Here also we will see friends there are various pistons are there for better understanding, then this is what we will call the surface where it will contact during the motion.

(Refer Slide Time: 03:29)



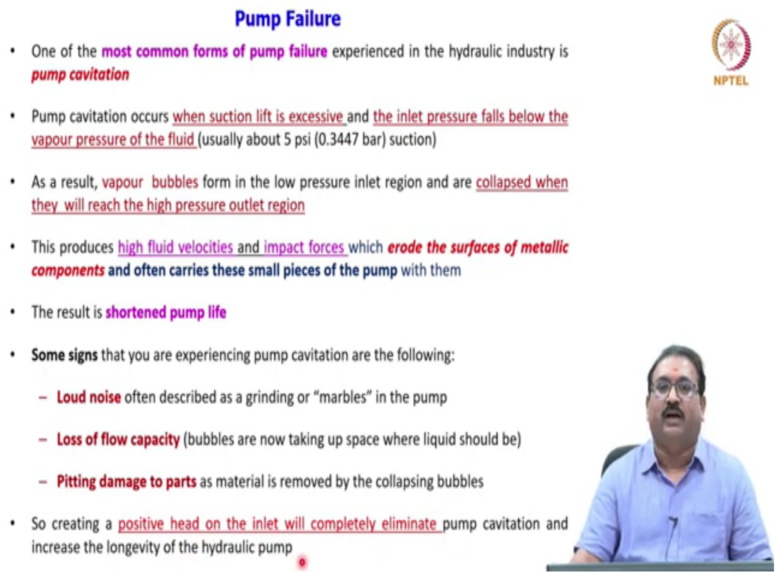
See here, there are various pistons are there during. Now, we will see friends the, this will make rotor is rotating, it will pushing the cylinder in and out through which the inlet and outlet is taking place, ok. This is also called as a reaction ring where the piston when it will thrown out it will touch to the inner surface, it is also called the reaction ring, and rotors are mounted eccentrically. This is called a pintle, one more name.

(Refer Slide Time: 04:01)



You will see. Now, the different design rotor is you will see different designs rotors. The movement of this rotor will pushes the piston in and out through which what happens? The inlets and outlet. Do not think there are so many inlets; all are staggered to the only one tank, ok. This is a different radial piston pump designs. This is actually a photograph of this.

(Refer Slide Time: 04:27)



After knowing the different types of piston pumps, quickly we will see, very quickly the pump failures, why the pump failures will takes place, what are the reasons. The one of the most common forms of pump failure experienced in hydraulic industry is a pump cavitation.

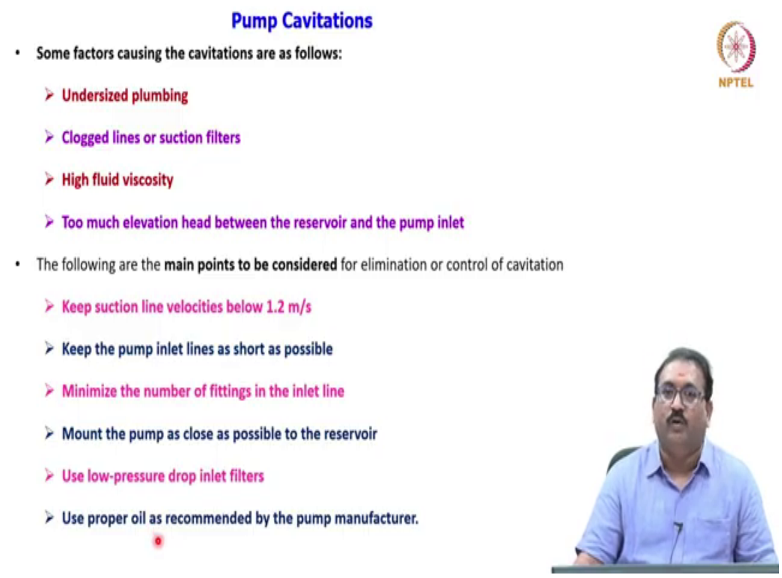
What is this pump cavitation? Pump cavitation occurs when suction lift is excessive and the inlet pressure falls below the vapour pressure of the fluid. Meaning usually it is about 0.3447 bar at the suction. As a result the vapour bubbles form in the low pressure inlet region and are collapsed when they will reach the high pressure outlet region.

This produces the high fluid velocities and impact forces. So, what? Which will erodes the surface of the metallic components and carries these small pieces of the pump with them during the exit. The result is shortened the pump life.

Some signs what you are seen in the cavitation, loud noise often described as a grinding or a marbles in the pump. Loss of flow capacity, meaning bubbles are now taking up space where the liquid should be that is why it is flow capacity is very less. The vapour bubbles are forming many in the suction site; otherwise it will sucks the full fluid. Pitting damage to the parts. At the exit what happened? They will make the impact the part. So, the pitting damage of the part.

So, creating the positive head on the inlet will completely eliminate the pump cavitation and increase the longevity of the hydraulic pump.

(Refer Slide Time: 06:48)

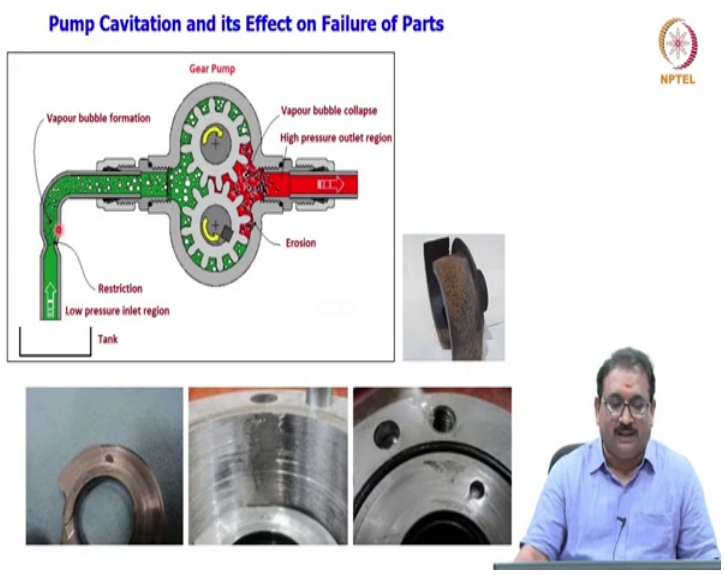


I will show you some of the factors causing the cavitations, apart from what I have discussed, undersized plumbing, clogged lines or a suction filters, high fluid viscosity, too much elevation head between the reservoir higher and the pump inlet.

So, the following are the main points to be considered for elimination or control of the cavitation. What we will do to overcome the cavitation? Keep suction line velocities below 1.2 meters per second. Keep the pump inlet lines as short as possible. Minimize the number of fittings in the inlet line. Mount the pump as close as possible to the reservoir. Use low pressure drop inlet filters.

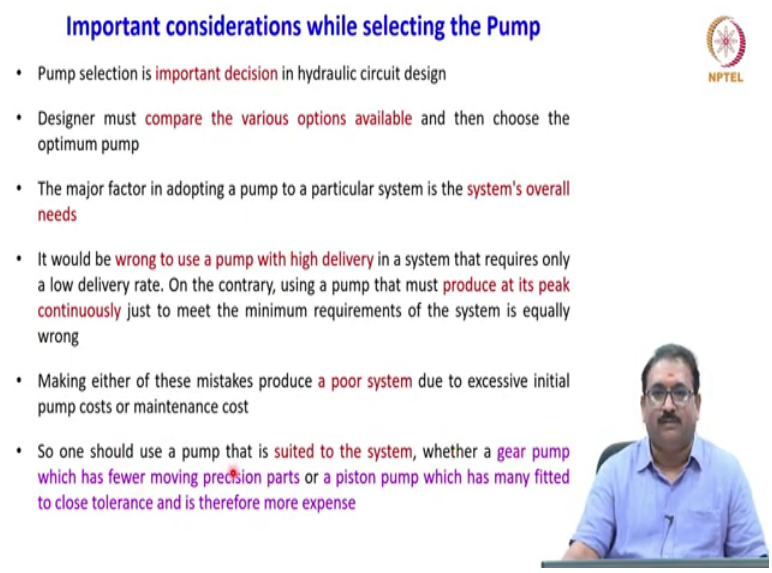
Use proper oil as recommended by the pump manufacturer because they will specify which type of oil you have to use with the various properties including viscosities also.

(Refer Slide Time: 08:11)



This is what I have told you at the inlet side low pressures region. What happens? Vapour bubbles will starts and they will grow; when they will reach the higher outlet side high velocity they will impact and they will make the pitting damage on the various parts. This will be severe if you are not taken care to overcome the cavitations. These are the failure parts.

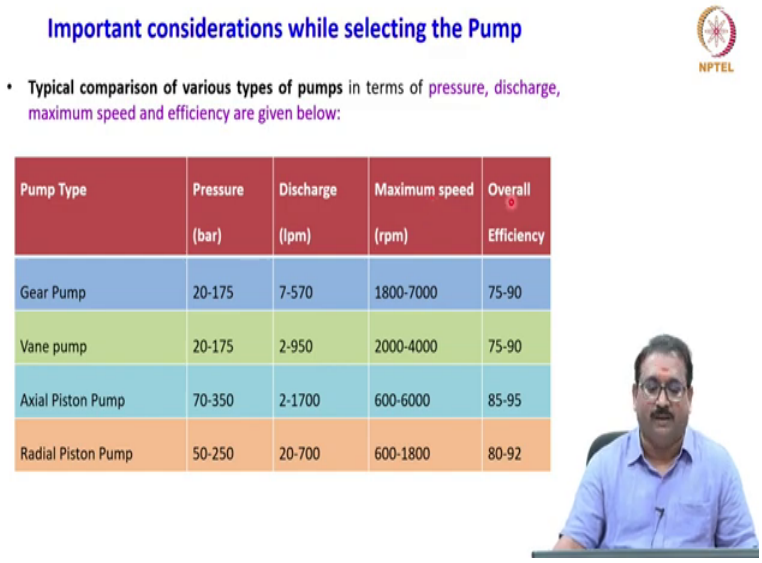
(Refer Slide Time: 08:41)



So, the important consideration while selecting the pump are, pump selection is important decision in hydraulic circuit design. Designer must compare the various options available and then choose the optimum pump. The major factor in adopting a pump to a particular system is the systems overall needs. It would be wrong to use the pump with high delivery in a system that requires only a low delivery rate. On the contrary, using a pump that must produce at its peak continuously just to meet the minimum requirement of the system is equally wrong.

Making either of these mistakes produce a poor system due to excessive initial pump costs or a maintenance cost. So, one should very careful while selecting the pumps, whether shall I use a gear pump which has a fewer moving parts also not. So, precise compared to the piston pump or shall I use a piston pump which has a large number of moving parts and all are close tolerance. Due to this it is more expensive as compared to the gear pumps.

(Refer Slide Time: 10:05)



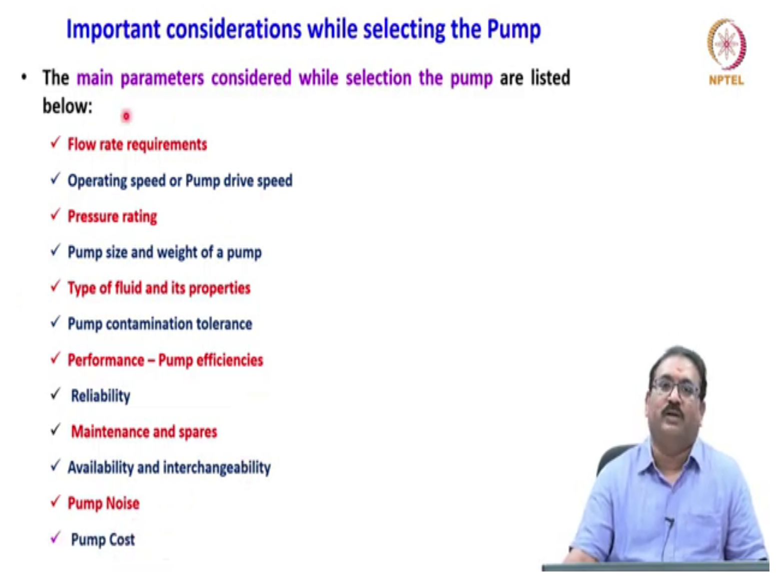
Pump Type	Pressure (bar)	Discharge (lpm)	Maximum speed (rpm)	Overall Efficiency
Gear Pump	20-175	7-570	1800-7000	75-90
Vane pump	20-175	2-950	2000-4000	75-90
Axial Piston Pump	70-350	2-1700	600-6000	85-95
Radial Piston Pump	50-250	20-700	600-1800	80-92

So, typical comparison of the various types of pumps in terms of pressure, discharge, maximum speed, efficiency, I am listed here for easy understanding the pump type, gear pump, vane pump, axial piston pump, radial piston pump, each you has a different pressure rating, discharge, maximum speed, overall efficiency.

You will see the gear pump pressure is 20 to 175 bar, discharge is 7 to 570 liters per minute, maximum speed is 1800 to 7000 rpm, overall efficiency 75 to 90, because of the leakage of oil more. Also they are not closed tolerance as compared to the axial piston pumps and the piston radial piston pumps.

Vane piston pumps are in between. Correct, you will see these characteristics while selecting which type of pump is required based on the pressure, discharge what your required, maximum speed, and overall efficiency.

(Refer Slide Time: 11:14)

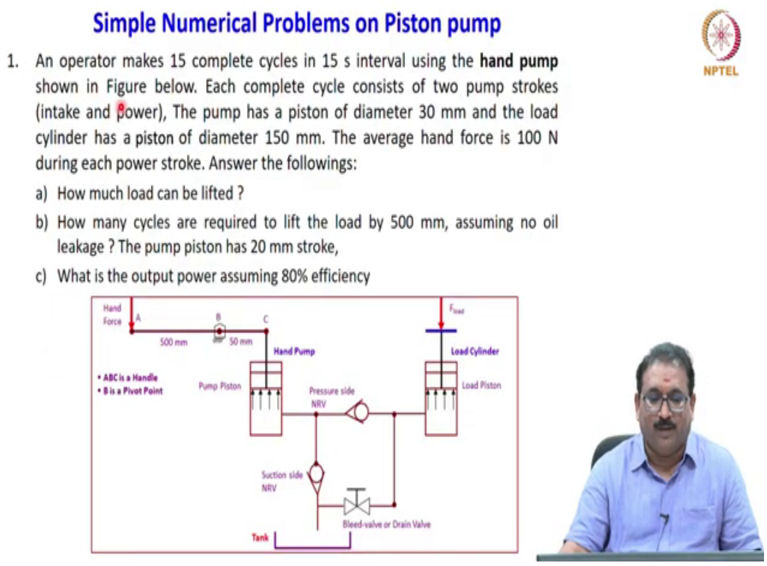


Also, we will see the main factors considered while selecting the pump are listed below. Please understand friend what is your flow requirement based on that you have to select the pumps. Then operating speed, meaning pump drive speed what is your pump drive speed is required. Or pressure rating, which pressure rating your working. Pump size and weight of the pump also matters.

Type of fluid and its properties, pump contamination tolerance, performance meaning efficiency characteristics because when you will by the pump or volumetric efficiency, mechanical efficiency, overall efficiencies are given for the each pump they are runned at the different speeds and different testing conditions at the laboratory you have to see that. Because what we are deriving now here it is a only based on the geometrical relationships, but actually the values are different.

They are giving when you will buy the pumps. Reliability, maintenance and spare parts, available in the market availability and interchangeability, pump noise, pump cost. These are some of the parameter you have to consider while selecting the pump for your applications.

(Refer Slide Time: 12:41)

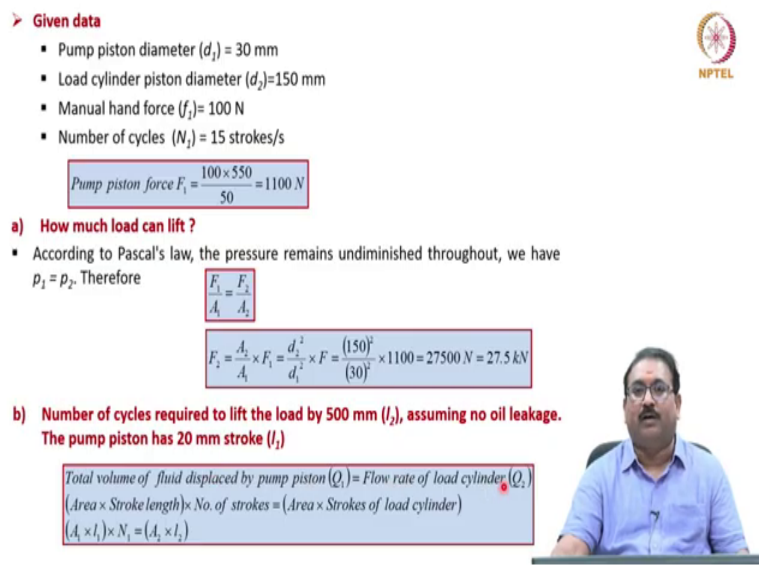


Now, quickly we will see some of the problems on the piston pumps this problem is depicting you; what is this? This is when you will see this it is a hand pump. An operator makes 15 cycles in 15 second interval using the hand pump shown in figure below. I already explained this. It is a hand pump. It is a load cylinder it is.

Each cycle consists of two pump strokes intake and power stroke meaning outlet. The pump has a piston diameter 30 mm and the load cylinder has a diameter 150 mm. The average hand force here only hand force 100 Newton, during each power stroke answer the following. How much load can we lift it?

Then, how many cycles are required to lift the load by 500 mm up, assuming no oil leakage? The pump piston has 20 mm stroke. Then c one is, what is the output power assuming the 80 percent efficiency?

(Refer Slide Time: 14:08)



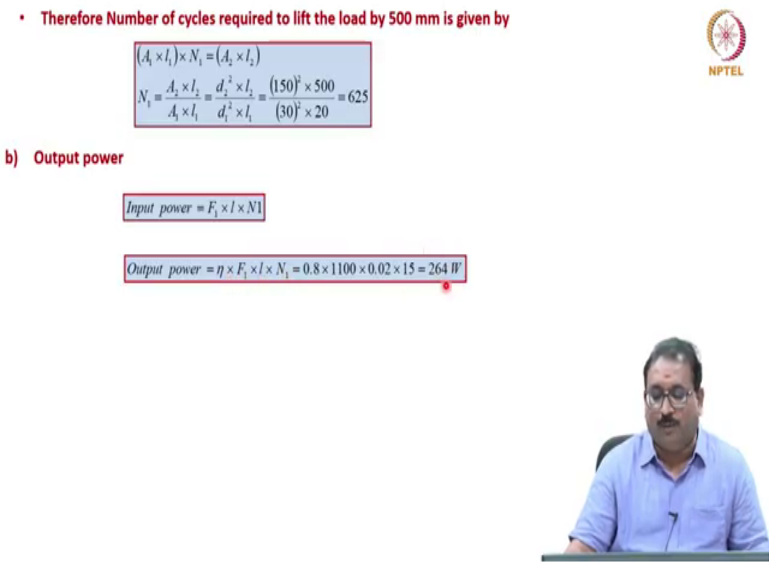
Quickly we will see friends how to do it this. The given datas are pump piston diameter is given load cylinder piston diameter is given. The manual force f 1 is given. The number of cycles is given 15 strokes per second. Then, the piston force, the manual force with leverage is there, no lever arm they are given, I am taken hundred into 550, this 500 plus 50 divided by the 50, the lever arm you will get 1100 Newton. Then, how much load can we lift?

Already we know that according to the Pascal's law p 1 equal to p 2, then F 1 by A 1 equal to F 2 by A 2. We required to find out F 2? F 2 equal to what? A 2 by A 1 into F 1. Here pi by 4 d 2 square, pi by 4 d 1 square pi by, 4 pi by 4 get cancelled, we will get d 2 square by d 1 square into F. F is what we are getting here, the pump piston force then I will get the load to be lifted is around 27500 Newton or 27.5 kilo Newton.

Similarly, next one is number of cycles required to lift the load. By how much? 500 mm. I will take you to the l 2 stroke it is. Assuming no oil leakage the pump piston has 20 mm stroke 1 1. How to do now? Now, the see here Q 1 equal to Q 2. What is Q 1? The total volume of fluid displaced by the piston pump is equal to flow rate of load cylinder. Meaning, what is the total volume displaced by the piston pump? Area into stroke into number of strokes is equal to area into strokes of load cylinder.

Here area is A 1 into l 1 multiplied by number of stroke N 1 equal to A 2 area of the load cylinder multiplied by the stroke l 2.

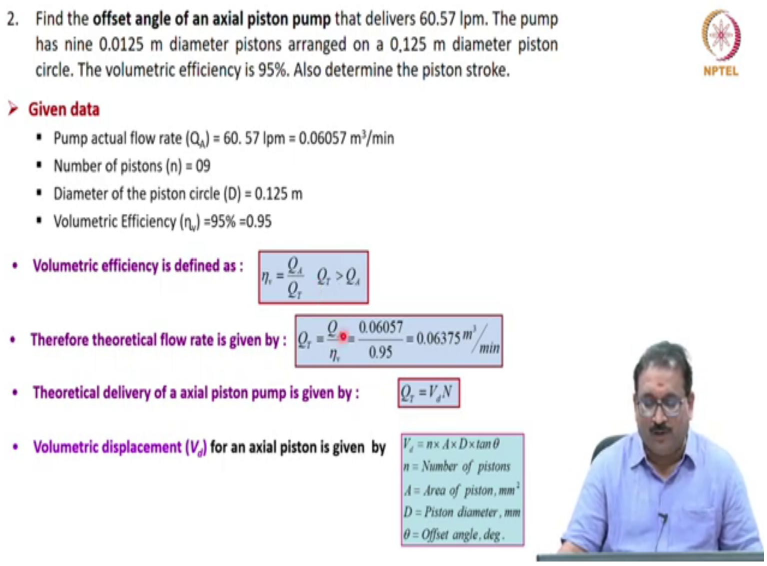
(Refer Slide Time: 16:15)



If you will do this, the thing is I am getting here I have substituting all values I want to find out N 1. Meaning 625 strokes are required to lift the load by 500 mm by substituting the values.

Now, output power, you know already we know that input power equal to F 1 into l stroke multiplied by the N 1 their output power is multiplied with volumetric efficiency what efficiency what they are given. Here efficiency F 1 l 1 N 1 you will get the output power is 264 Watt.

(Refer Slide Time: 16:53)

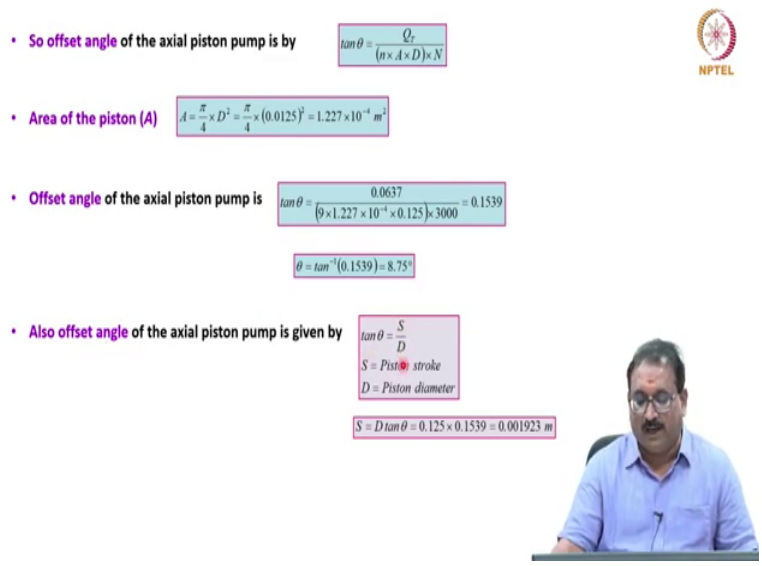


Now, we will move on to the one more problem on the axial piston pump. Here find the offset angle of the axial piston pump that delivers 60.57 liters per minute. The pump has nine 0.0125 meter diameter pistons arranged on 0.125 diameter pistons circle. The volumetric efficiency is 95 percent also determine the piston stroke.

What are the given data friends? Pump actual flow rate is given now. lpm I converted into m cube per minute. Number of piston is given as 9. Diameter of the piston circle diameter, diameter is given piston. Volumetric efficiency is given, then volumetric efficiency already we know that in the formula Q A by Q T are always Q T is greater than the Q A.

Therefore, what you will do? The Q A is given volumetric efficiency is given then you will calculate the Q T, Q T is you will get this much then theoretical delivery of the piston pump is given by Q T equal to V d into N friends. Then, volumetric displacement of the axial piston pump is given by V d equal to already we are seen, N is the number of pistons multiplied by the area into d multiplied by tan theta.

(Refer Slide Time: 18:28)

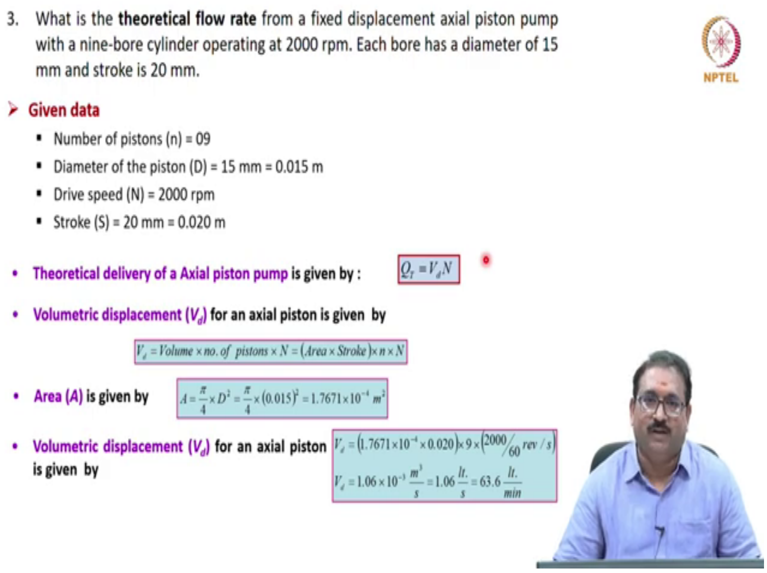


Theta is the offset angle, then what we will do? So, the offset angle tan theta is given by Q T by n A D into N, substitute all the values. Here we will see A is nothing but a pi by 4 piston D square. I will get this much.

Offset angle tan theta is given by after substituting all I will get 0.1539 or theta equal to 8.75 degrees. Also, we will remember already we know that the offset angle tan theta equal to S by D, S is the piston stroke by piston diameter you will get S, S is equal to D into tan theta, D already is given diameter of the piston. You will get this much stroke.

Please remember friends whatever the problems only they are playing with these parameters, these parameters.

(Refer Slide Time: 19:22)

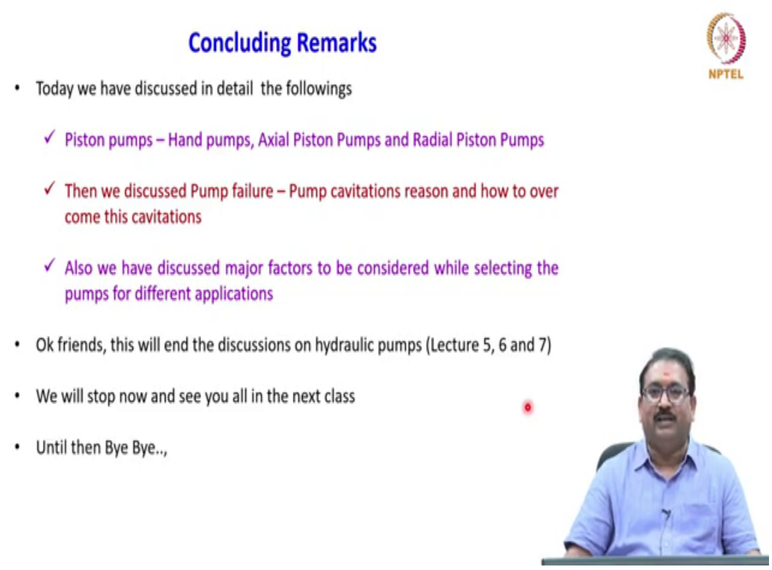


One more quickly we will see now, what is the theoretical flow rate from a fixed displacement axial piston pump with a 9 bore cylinder operating at 2000 rpm. Each bore has a diameter of 15 mm and a stroke of is 20 mm. Then, given data number of pistons, diameter of the pistons, drive speed, stroke.

Please remember friends units are very very important. You will convert all into single units. One you do not convert meter, another you will convert mm, no. All should be in the same unit.

Theoretical delivery of the axial piston pump Q T equal to V d into N, then volumetric displacement V d is given by volume into number of pistons into N. This volume is nothing, but area into stroke into small n number of pistons and capital N is a drive shaft x speed. So, area this is a one, then I am substituting all the values I will get V d equal to 1.06 liters per second or you will get 63.6 liters per minute. You will see all are very simple. They will follow these simple equations. Using the geometry you are able to quickly you will ascertain what is your volumetric efficiency all you have to calculate, ok.

(Refer Slide Time: 20:50)



I will conclude today's lecture. Today we have discussed in detail the following, piston pumps, hand pumps, axial piston pumps, radial piston pumps and different variants. Then we discuss the pump failure because of the pump cavitations, what are the reasons, how to overcome these cavitations. Also, we have discussed the major factor to be considered while selecting the pumps for different applications.

Ok friends, this will end the discussions on hydraulic pumps. This is covered in the lecture 5, lecture 6, and lecture 7 in detail. Each lecture is on the gear pump, vane pump, and a piston pumps.

We will stop now, and see you all in the next class. Until then goodbye. Thank you one and all for your kind attention. [FL].

Thank you.