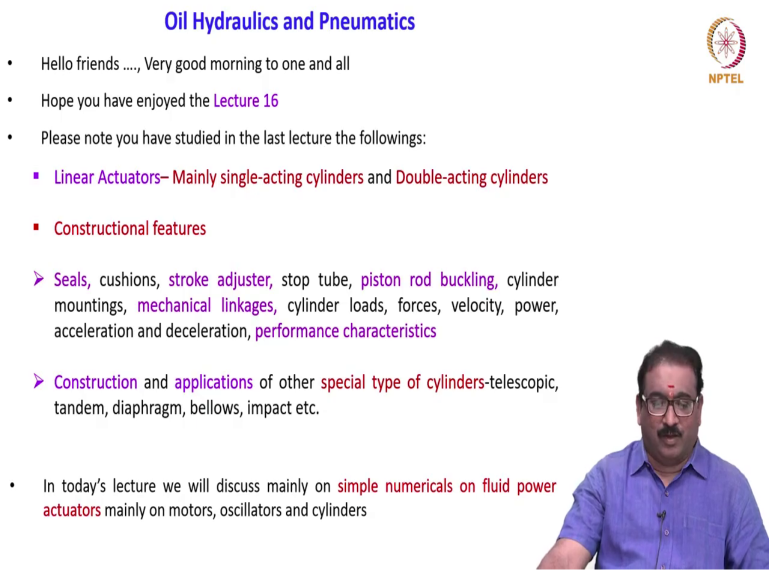
Oil Hydraulics and Pneumatics
Prof. Somashekhar S
Department of Mechanical Engineering
Indian Institute of Technology, Madras

Part 1: Numericals on Hydraulic Motors - Speed, Theoretical torque, Theoretical power, Volumetric efficiency, Mechanical efficiency, Overall efficiency etc.
Lecture - 56
Numericals on Fluid Power Actuators

(Refer Slide Time: 00:23)



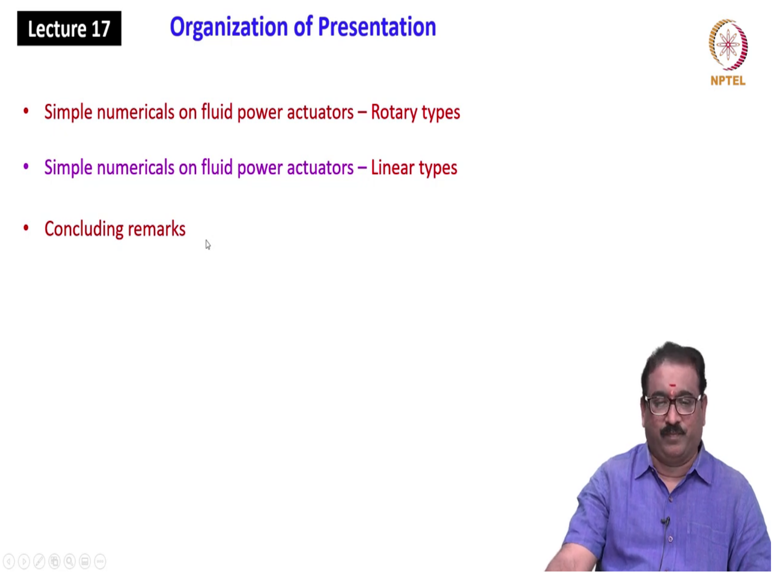
My name is Somashekhar, course faculty for this course. Hello friends, very good morning to one and all. Hope you have enjoyed the last lecture 16. Please note you have studied in the last lecture the followings; linear actuator basically on single acting cylinders and double acting cylinders.

Constructional features, which includes seals, cushions, stroke adjuster, stop tube, piston rod buckling, cylinder mountings, mechanical linkages, cylinder loads, push loads, and a pull loads, forces, velocity, power, acceleration and a deceleration, and performance characteristics, basically the volumetric efficiency, mechanical efficiency, overall efficiency for the cylinders.

We are also seen in the last lecture, the constructional details and applications of special type of cylinders telescopic cylinders, tandem cylinders, diaphragm cylinders, bellows actuators, impact cylinders, these are special actuator mainly used in the pneumatics. In today's lecture friends, we will discuss mainly on the simple numericals on fluid power actuators, as because you have seen in the last two lectures lecture 14 and 15 are devoted to the constructional and operation details of rotary actuator and a linear actuator.

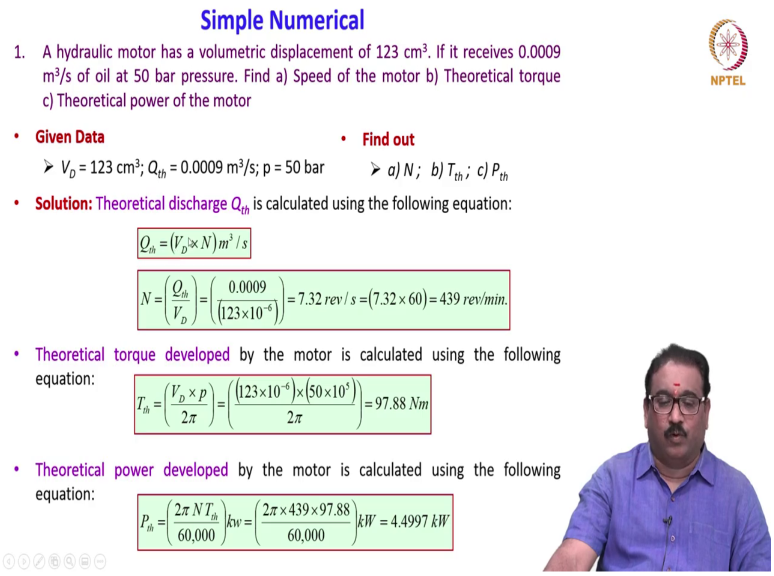
In today's class we will discuss the simple numericals mainly on motors, oscillators, and cylinders.

(Refer Slide Time: 02:28)



Now, let us we will see the organization of presentation of lecture 17,.which includes as I have told you simple numericals on the rotary types actuator and a linear types actuator and then I will conclude today's lecture.

(Refer Slide Time: 02:49



Let us we will take the first problem, first we will see the problems on hydraulic motors. A hydraulic motor has a volumetric displacement of 123 centimeter cube, if it receives 0.009 m cube per second of oil at a 50 bar pressure. Find a speed of the motor, theoretical torque, then theoretical power of the motor.

As we know these are the given data volumetric displacement V D is given theoretical flow rate is given and a pressure is given. What we have to do? We have to find out the N speed of the motor, theoretical torque, and the theoretical power using the given data. Already we know that, the theoretical discharge is calculated using the following relation; Q th equal to V D to N.

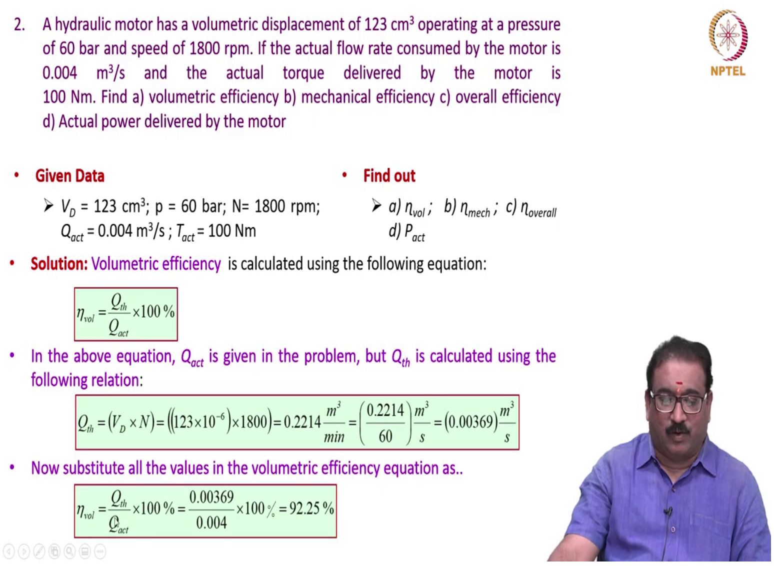
Here, we want the N that is why you will take the Q th by V D. These are the given data substitute the values please take care friends I am substituting all in the same units SI units.

Now, we will get it the N equal to 7.32 revolution per second, if you will multiplied by 60 it will give the revolutions per minute, whatever the unit you want you will do it very easily like this.

Then theoretical torque, developed by the motor is calculated using the simple relation T th equal to V D into p divided by 2 pi. Substitute all the values again here you will see here V D again I am substituting in the meter cube and p is in the Newton per meter square because, here they are given 50 bar 1 bar equal to 10 to the power of 5 Pascal, then divided by 2 pi. Then, we will get 97.88 Newton meter.

Then, theoretical power developed by the motor is calculated using the equation P th equal to 2 pi N T by 60,000 kilo watt, substitute the value you will get 4.4997 kilo watt. Very simple friends here, these are the very important equation theoretical flow and theoretical torque how to calculate and a power how to calculate. If you know all three important formulas any parameter they will give you will substitute and you will get it, but please take care the units should be very very important.

(Refer Slide Time: 05:45)



Now, let us we will see the one more problem. A hydraulic motor has a volumetric displacement of 123 centimeter cube operating at a pressure of 60 bar and a speed 1800 rpm. If the actual flow rate consumed by the motor is 0.004 m cube per second and the actual torque developed by the motors 100 Newton meter.

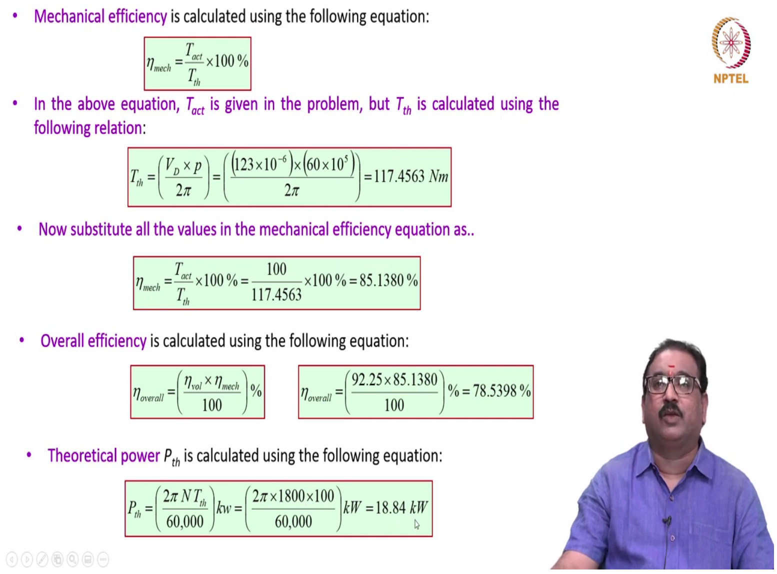
Now, our objective is to find out, what we have to find out? Volumetric efficiency, mechanical efficiency, overall efficiency, and actual power delivered by the motor. You will see all are very very important performance characteristics of the any actuator now; here it is a hydraulic motor. Let us we will see now the given data these are the given data V D is given, p is given, N is given, actual flow rate is given, theoretical actual torque is given.

Now, what we have to find out? We have to find out all the efficiency, volumetric efficiency, mechanical efficiency, overall efficiency, and yeah here is the actual power delivered by the motor. Now, from this the volumetric efficiency is calculated using the following equation, volumetric efficiency is a ratio of the theoretical flow rate to the actual flow rate multiplied by 100.

Then in the above equation, Q actual is given in the problem, Q theoretical is calculated using the simple relation V D into N as you have seen in the previous problem. Substitute all in the given problem; then we will get here 0.00369 m cube per second.

Now, substitute this calculated Q th in the above equation to get the volumetric efficiency, as because Q theoretical we have calculated here the actual flow rate is given here, then we are getting 92.25 percent volumetric efficiency.

(Refer Slide Time: 07:53)

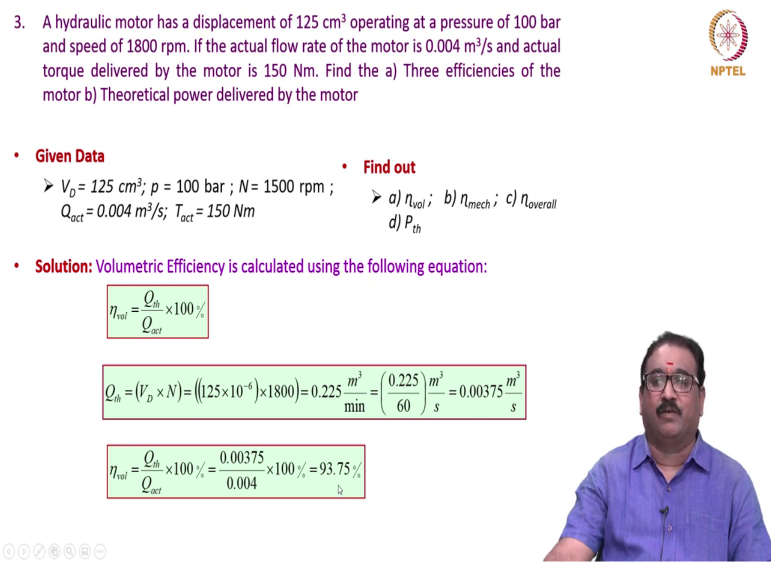


Now, mechanical efficiency is calculated using the following equation, mechanical efficiency is the ratio of actual torque divided by theoretical torque multiplied by 100, then in the above equation again T actual is given in the problem, but T theoretical is calculated using the same equation as we have seen in the previous problem V D into p divided by 2 pi. Now, substitute all the values friends here, you will get the 117.4563 Newton meter.

Now, you will substitute this theoretical torque, I know the actual torque given in the problem we will get the mechanical efficiency is 85.1380 percentage. After knowing the volumetric efficiency and a mechanical efficiency, the overall efficiency is nothing but multiplying the these two, which is given by overall efficiency volumetric efficient into mechanical efficiency.

Substitute the values here, you will get 78.5398 percentage is the overall efficiency. Now, theoretical power is calculated using the this 2 pi N T by 60,000 kilo watt it is ok, substitute all the values I will get 18.84 kilo watt.

(Refer Slide Time: 09:22)

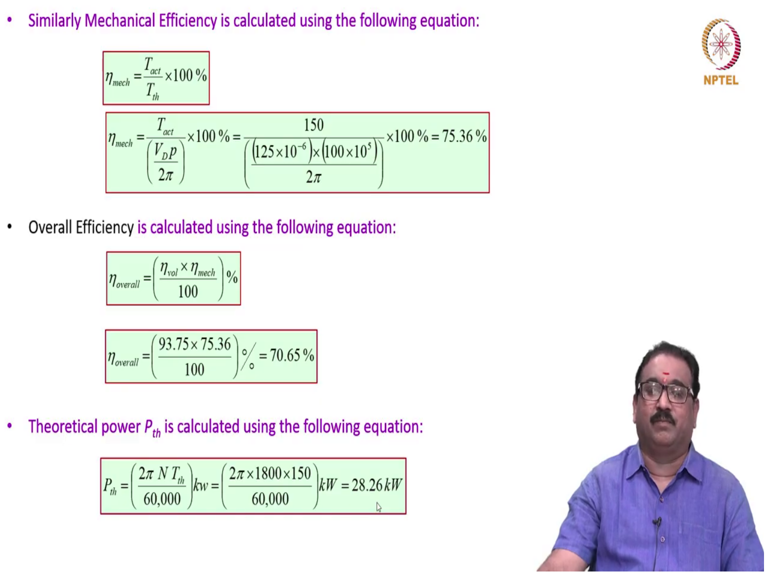


Let us we will move to third problem a hydraulic motor has a displacement of 125 centimeter cube operating at a pressure of 100 bar and a speed of 1800 rpm. If the actual flow rate of the motor is 0.004 m cube per second and actual torque delivered by the motor is 150 Newton meter.

Find the 3 efficiency of the motor and theoretical power delivered by the motor. It is similar to the previous problem, but data's are changed here. Shall we do very quickly now here, the given data's are V D p N Q actual and a T actual these are the given data, then find out all the efficiencies and the theoretical power.

Now, we will see the volumetric efficiency is calculated using the this equation substitute, but here as I have told you the Q theoretical is not given V D into N substitute the values here we will get 0.00375 m cube per second. Now, we will calculate the volumetric efficiency because, I know the theoretical flow rate and actual flow rate; substitute the values I will get the volumetric efficiency 93.75 percent.

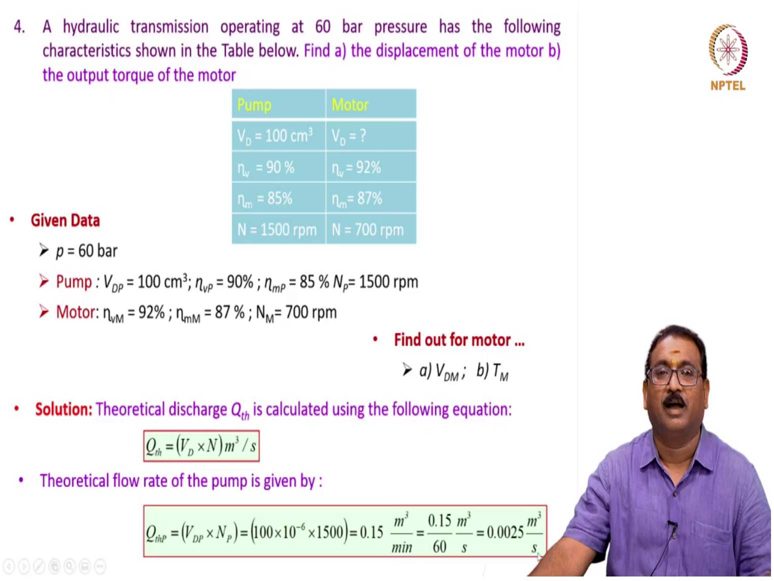
(Refer Slide Time: 10:51)



Next we will move on to the mechanical efficiency, which is the ratio of T actual divided by T theoretical into 100. Now, here also T T theoretical we do not know I am substituting directly in this here V D into p divided by 2 pi, substitute all the units I will get the mechanical efficiency is 75.36 percentage.

Now, overall efficiency as I have told multiplied by these two you will get 70.65 percentage. Now, power theoretical power is calculated using 2 pi N T by 60,000 kilo watt it is, substitute all the values you will get 28.26 kilo watt power.

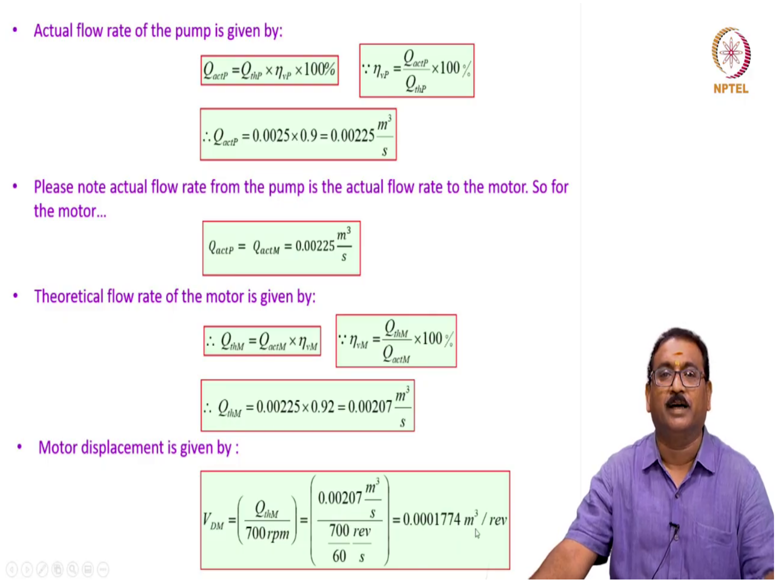
(Refer Slide Time: 11:38)



Let us we will see, one more problem a hydraulic transmission operating at 60 bar pressure has the following characteristics shown in the table below. Find the displacement of the motor and the output torque of the motor. The pump characteristics are given in the table, motor characteristics are given then, these are the given data the pressure is given 60 bar all the parameters are given, please take care the units very important.

Then find out V D of the motor and output torque of the motor I am using the convention m for the motor p for the pump. The solution is very simple here, as we already know theoretical discharge Q theoretical is calculated using the following relation Q theoretical equal to we know already V D into N. Now, theoretical flow rate of the pump is given by substitute all the values, in the same unit I may get 0.0025 m cube per second after converting.

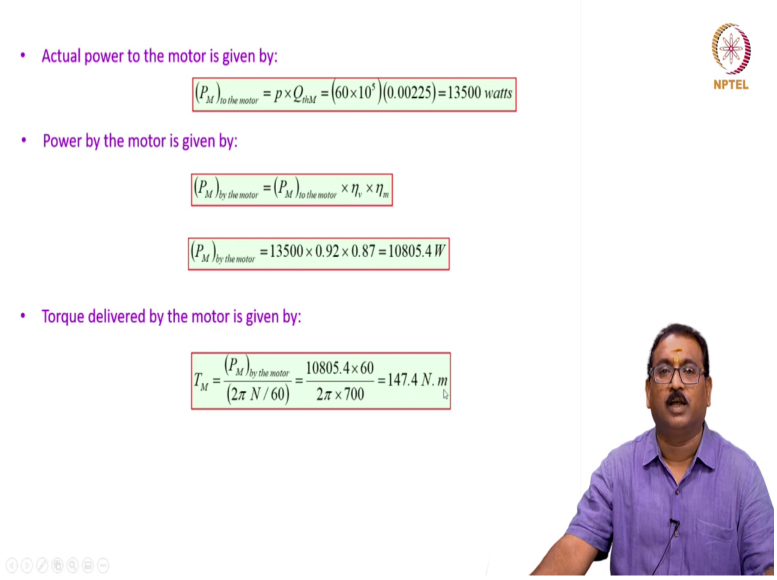
(Refer Slide Time: 12:55)



Now, actual flow rate of the pump is given by actual Q actual P equal to Q theoretical for the pump multiplied by the volumetric efficiency which is given by after multiplying this volumetric efficiency we may get 0.0025 m cube per second. Please note actual flow rate from the pump is the actual flow rate to the motor. So, the motor Q actual P equal to Q actual motor this will come here because, whatever the fluid is ejected from the pump it will go to the inlet to the motor.

So, theoretical flow rate of the motor is given by Q theoretical equal to Q actual into the volumetric efficiency of the motor. So, Q theoretical motor equal to whatever the Q actual is there multiplied by the volumetric efficiency of the motor, which will give you 0.00207 m cube per second. So, the motor displacement is given by V D of the motor is given by Q theoretical motor divided by the speed of the motor, which will be given as 0.001774 m cube per revolution.

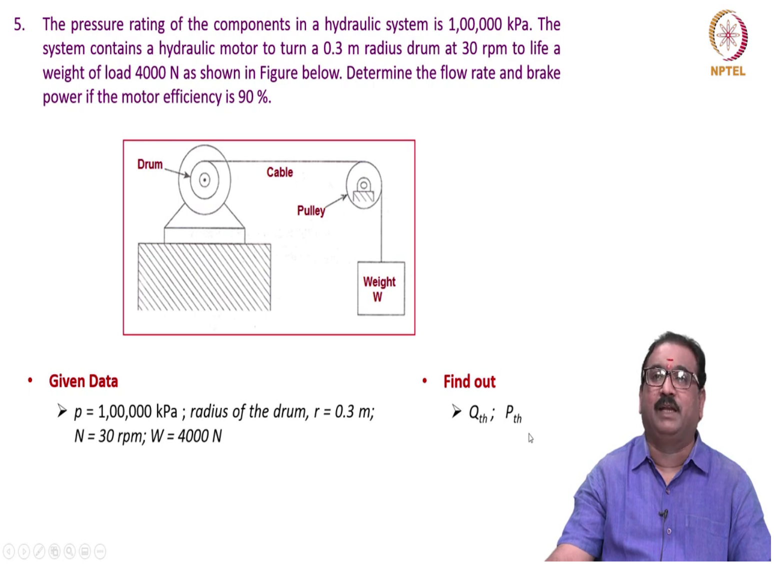
(Refer Slide Time: 14:28)



Now, the actual power to the motor is given by p pressure p into Q theoretical of the motor. The p is given as 60 bar it is i am converting into Newton per meter square multiplied by the Q theoretical of the motor, which will give you 13,500 watts. So, power by the motor is given by P M multiplied by the volumetric efficiency multiply by the mechanical efficiency, which will be given as after multiplying all these things I may get 10805.4 watt.

The torque delivered by the motor is given by T M is P M of the motor divided by 2 pi N again 60 is a convention factor, after doing this I may get 147.4 Newton meter ok.

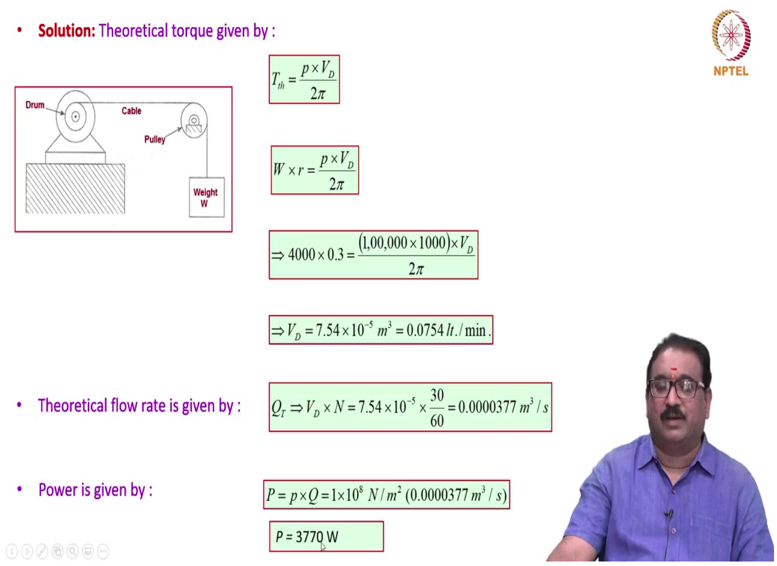
(Refer Slide Time: 15:34)



Now, we will see one more problem the pressure rating of the components in a hydraulic system is 1,00,000 kPa. The system contains a hydraulic motor to term a 0.3 meter radius drum at 30 rpm to lift the weight of a load 4000 Newton as shown in the figure here. Determine the flow rate and the break power if the motor efficiency is 90 percent, very very simple problem here it is. Here I am using the motor to lift the load using the cable and pulley arrangement.

Now, same friends how to do, given data is p is given radius of the drum r is given this is required to calculate the torque; torque equal to what? Load multiplied by the distance very simple it is. Then N is given 30 rpm and W is given 4000 Newton. What we have to find out? Q th and P th.

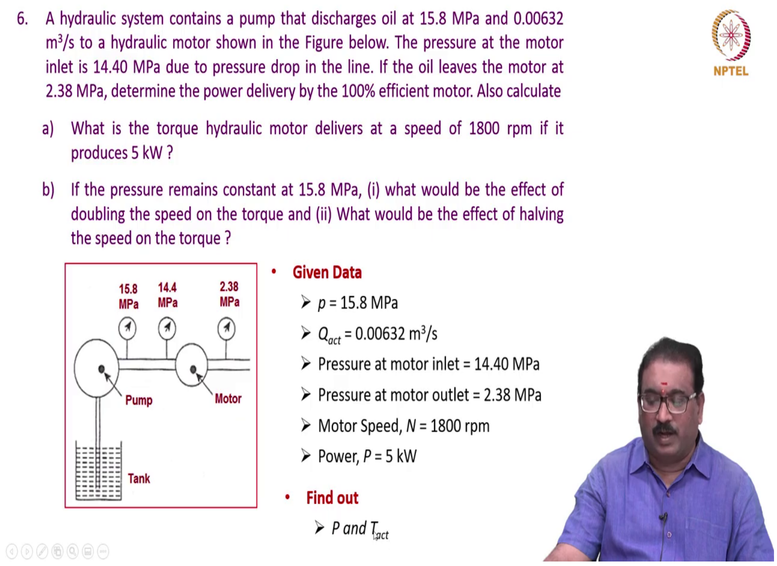
(Refer Slide Time: 16:50)



Now, we will move to solution, theoretical torque given by T theoretical p into V D by 2 pi. Already we know that the torque is given by weight multiplied by the radius equal to p into V D by 2 pi. Now, substitute all the values the unknown parameter is V D, all the parameters are known please keep in mind you will put it in the same units.

Now, V D is given by 0.0754 liters per minute, now the theoretical flow rate is given by V D into N, you substitute all the parameter you will get 0.0000377 m cube per second. Now, very easy power is given by pressure into flow rate substitute all the values afterward I am getting the power is 3770 watt.

(Refer Slide Time: 17:58)



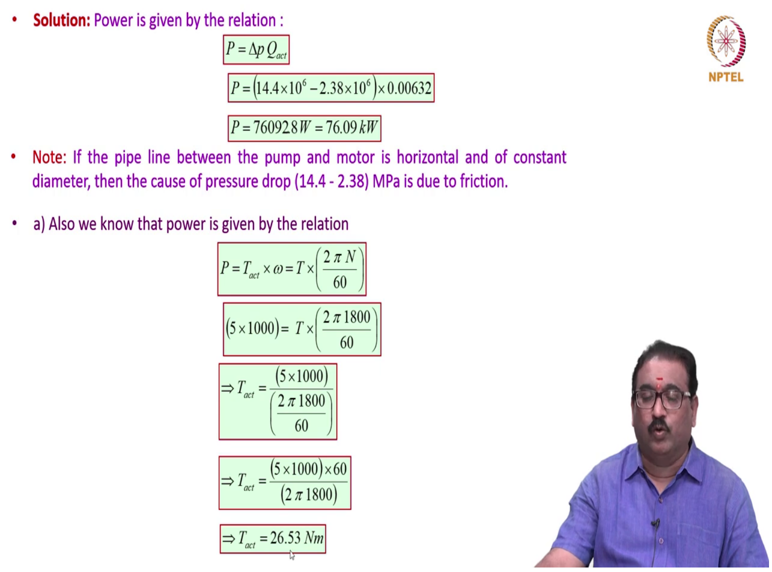
Now, we will move on to the one more problem, a hydraulic system contains a pump that discharges oil at 15.8 mega Pascal and 0.00632 m cube per second to a hydraulic motor shown in the figure below. The pressure at the motor inlet is 14.40 MPa due to pressure drop in the line. If the oil leaves the motor at 2.38 mega Pascal, determine the power delivery by the 100 percent efficient motor. Also calculate what is the torque hydraulic motor delivers at a speed of 1800 rpm if it produces a 5 kilo watt power.

If the pressure remains constant at 15.8 MPa, what would be the effect of doubling the speed on the torque and what would be the effect of halving the speed on the torque?

Now, here you will see friends here a tank, a pump, a motor the pressures are given here the pump pressure outlet pressure is 15.8, the inlet pressure to the motor is 14.4, the outlet pressure is 2.38 mega Pascal. Correct, these are the given data p is given, Q actual is given pressure at the motor inlet, pressure at the motor outlet is given correct and then power is 5 kilo watt.

Now, what is our objective? Our objective is to find out the power delivered by the motor and actual torque.

(Refer Slide Time: 20:00)



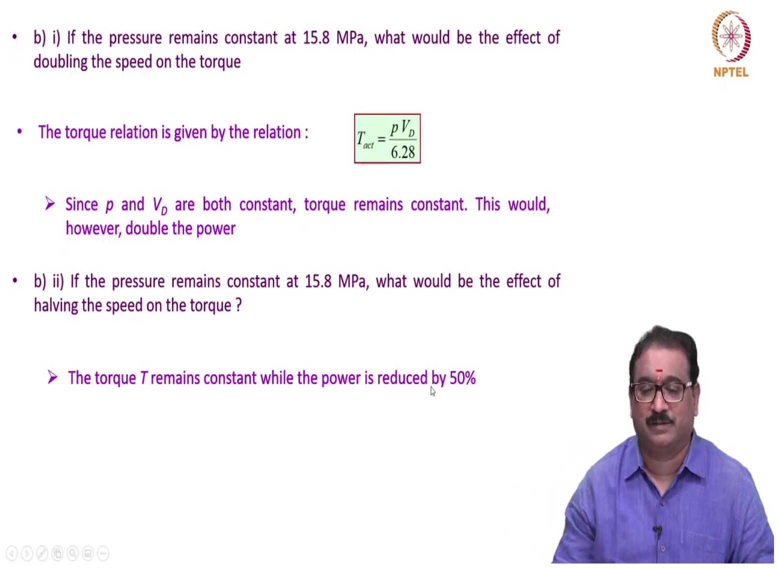
Let us we will see very quickly power is given by the relations as we know delta P into to Q actual, delta P is written as the inlet and outlet the differential pressure we are writing here multiplied by the actual flow rate.

Then we will get here, this is the watt then divided by 1000 it will use the kilo watt. Please note friends here if the pipeline between the pump and motor horizontal and of constant diameter, then the cause of pressure drop 14.4 MPa minus 2.38 MPa is due to the friction.

Also we know that the power is given by the relation T actual into omega omega is 2 pi N by 60.

Now, substitute all the values the power is given I am writing in the watt, then unknown parameter is T. Now, you will make the calculation T actual is given by 26.53 Newton meter.

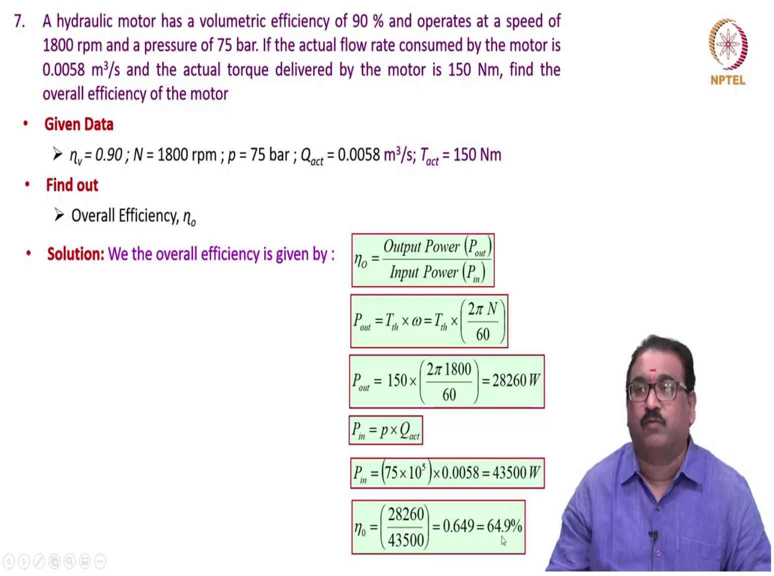
(Refer Slide Time: 21:20)



Then for the b if the pressure remains constant at 15.8 MPa, what would be the effect of doubling the speed on the torque already we know that, the torque relation is given by T actual equal to p into V D by 6.28, when we are doubling the speed on the torque.

Since p and V D are both constant, the torque remains constant. This would however, doubles the power. The b is here, if the pressure remains a constant at 15.8 MPa, what would be the effect of halving the speed on the torque? The torque T remains constant while the power is reduced by 50 percent.

(Refer Slide Time: 22:14)



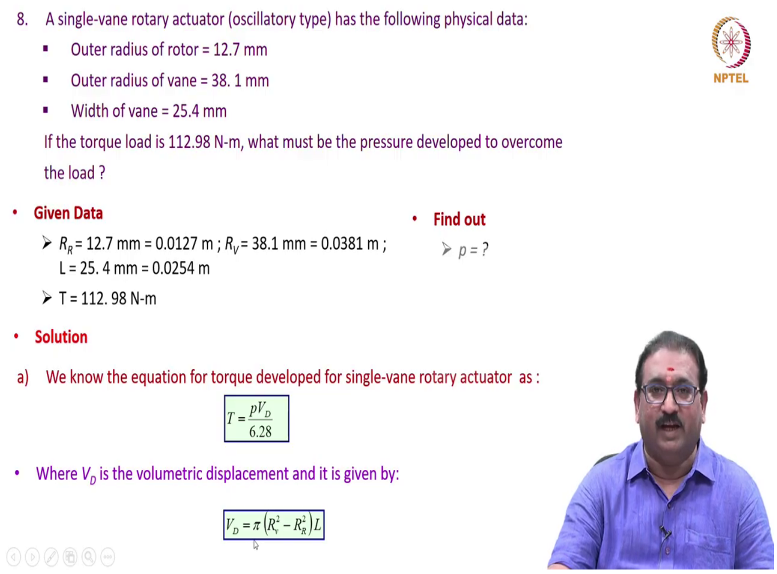
Then one more problem you will see, the hydraulic motor has a volumetric efficiency of 90 percent and operates at a speed of 1800 rpm and a pressure of 75 bar. If the actual flow rate consumed by the motor is 0.0058 m cube per second and actual torque delivered by the motor is also given 150 Newton meter, and find the overall efficiency of the motor.

Already we know that, we have to find out the input power and the output power, the input power is always the hydraulic power output power is always the mechanical power.

So, these are the given data's in this problem, the volumetric efficiency is given N is given, p is given, Q actual is given, T actual is given. Now, we have to find out the overall efficiency, the overall efficiency as I have told you output power by input power. The output power is calculated T theoretical into omega; omega is I am writing 2 pi N by 60 substitute all the values I will get 28260 watt.

Then P in that is a power n equal to p into Q actual, which is given by substitute the values in the Newton per meter square and multiply by the Q actual I will get 43500 watt. Now, quickly we will take the ratios output power by input power I will get the overall efficiency is 64.9.

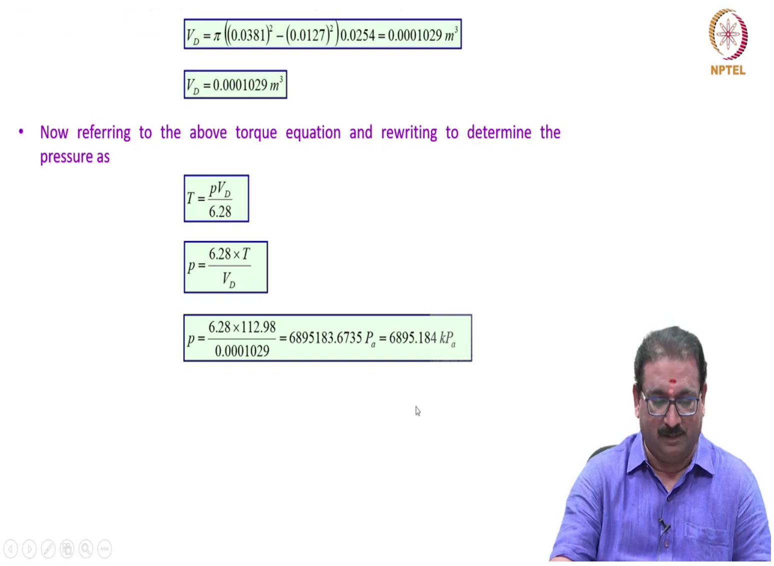
(Refer Slide Time: 23:59)



Let us we will see one more problem on oscillatory type of motors. A single vane rotary actuator has the following physical data: outer radius of rotor 12.7 mm, outer radius of vane 38.1 mm, width of the vane 25.4 mm. If the torque load is 112.98 Newton meter, what must be the pressure developed to overcome the load? Let us we will quickly list out what are the given data, as I have told you R R I am using for the radius of the rotor, radius of the vane, the width of the vane L, and the torque load T these are the given data, our objective is to find out the pressure developed to overcome the load.

Now, already we know that friends, the equation for torque developed for a single vane motor which is given by T equal to p V D by 6.28, this is a standard equation what we have developed for the oscillatory single vane motor. All these numericals are based on the previous classes, please see once again all the lectures, then what we will do V D is the volumetric displacement here, p is the pressure volumetric displacement is given by V D equal to pi R v square minus R R square into L.

(Refer Slide Time: 25:46)



After substituting all the values I will get the V D equal to 0.001029 m cube. Then, now referring to the above equation torque equation and rewrite the term to determine the pressure as T equal to we know already p V D by 6.28.

Now, we want now pV want pV want multiply this divided by V D substitute all the values given here quickly we will get it this is in Pascal then, divided by 1000 you will get it in the kilo Pascal, you put it in any unit here mega Pascal bar or whatever it is. Now, I am putting in the kilo Pascal.