Oil Hydraulics and Pneumatics
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Part 2: Numericals on Hydraulic Cylinders- Extension and Retraction Speed, Extension and Retraction Load Carrying Capacity, Power, Flow rate etc.
Lecture - 57
Numericals on Fluid Power Actuators

My name is Somashekhar, course faculty for this course.

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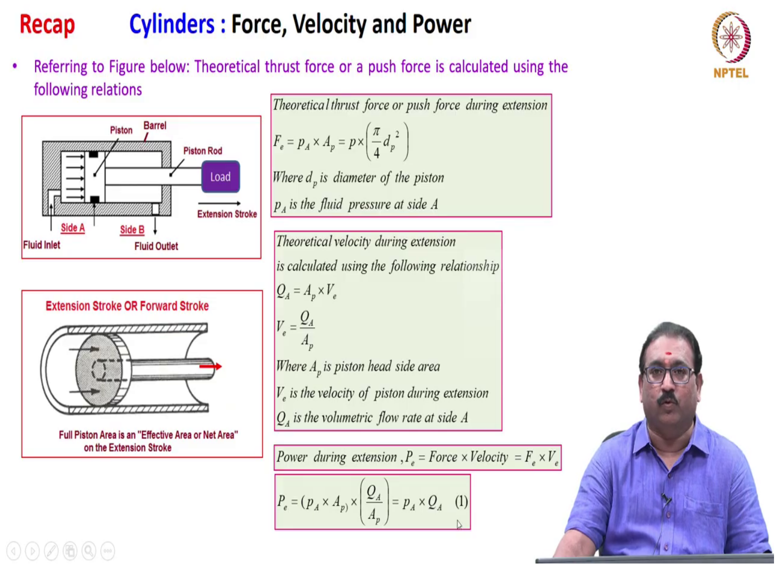

Now, quickly we will move on to the some simple numericals on the cylinders, which is again based on the previous class what we discussed on the cylinders. Quickly, I will recap in which the important terminologies are force, velocity and a power. Using this, you have to calculate any numericals on the cylinders.

The basic is this. As we know already here I have shown the figure theoretical push force or a thrust force is calculated using the following equations. You see friends here it is a double acting single rod cylinder. To push this load, the pump port is open to the side A. And whatever the fluid is at the side B, it will go to the tank. Here the effective area is a piston area, please understand this piston area.

Therefore, the thrust force or the push force is calculated using pressure acting over this p A into A p; already we are seen A p is pi by 4 d p square piston area. Similarly, the theoretical velocity we are calculating the simple equation the Q equal to A V here we want the V e Q A by A p, A p is the piston head area.

Now, similarly power during the extension is force into velocity. Force for the extension, and velocity for the extension. Similarly, you substitute all the values, you will get the power for the extension is p A into Q A.

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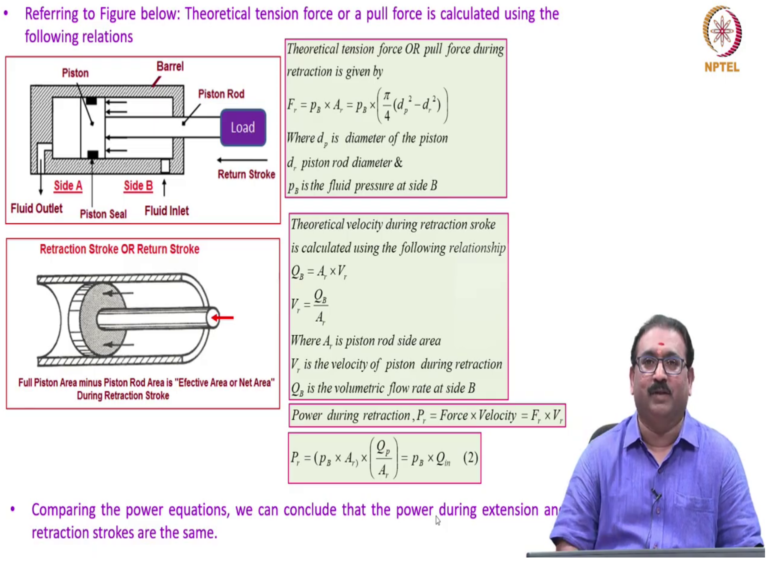

Similarly, during the retraction as I have told you this is a theoretical tension force or a pull force through the fluid. Now, the fluid inlet is this; fluid outlet is this. Here please understand friends here when we are calculating the return force p B into A r. A r is a, what is this? A r is a area rod area. Here this area. This is pi by 4 d p square minus d r square. This is very very important.

Now, similarly, the velocity is the V r equal to Q B by A r. We have seen already this equation in the previous class. These are very essential to understand the numericals. Similarly, power equal to force into velocity; here the force is force required during the retraction multiplied by the velocity of retraction or P r equal to p r into A r Q p by A r; A r, A r will get cancel. Here p b into Q B.

Here already we know that comparing the power equation for both, we can conclude that the power during the extension and retraction strokes are the same.

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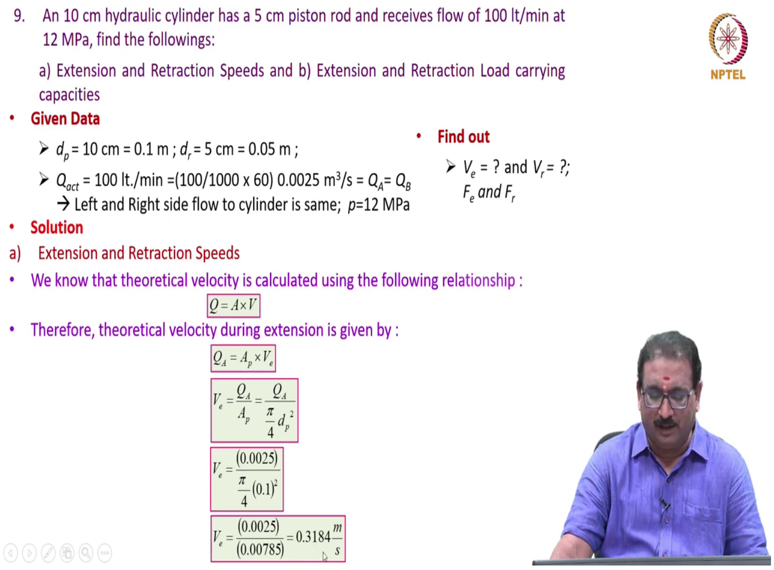

Keeping in mind, let us we will move quickly to the problems. An 10 centimeter hydraulic cylinder has a 5 centimeter piston rod and receives a flow of 100 liters per minute at 12 MPa, find the followings. Extension and retraction speeds velocity he asked and extension and retraction load carrying capacity.

Meaning he asked the force during the extension and retraction. These are the given data. All the problem you will try to list all the given data, and see here d p diameter of the 10 centimeter, but we will convert all into the single unit that single unit that is a meter. Then I am converting here 0.1 meter, then rod area 5 centimeter, again divided by 100, it will give us 0.05 meter. Q actual also liters per minute is there.

What you will do? You will convert into meter cube per second or minute. Now, I converted meter per second by dividing 1000 into 60. If you want meter cube per minute, you no need to divide by 60.

But all should be in the same unit, please remember which is a both side flow Q A equal to Q B. Left and right-side flow to the cylinder are of same it is. Then also they are given the pressure the 12 Mega Pascal you will convert into Pascal multiplying by 10 to the power of 6.

Now, what is our objective? Our objective is to find out the extension and retraction speed V e and V r. And also you will find out extension and retraction load carrying capacity F e and F r. Now, already we know that extension and retraction speeds meaning calculated using the general equation Q equal to A V.

Then V equal to what it is? Q by A. Therefore, now we will go the theoretical velocity during the extension I am using the notation Q A at the left side flow A p into V e. Then V e equal to Q A by A p, very simple, A p is a pi by 4 d p square. Now, we will substitute the values given values then you will get velocity for extension is 0.3184 meters per second.

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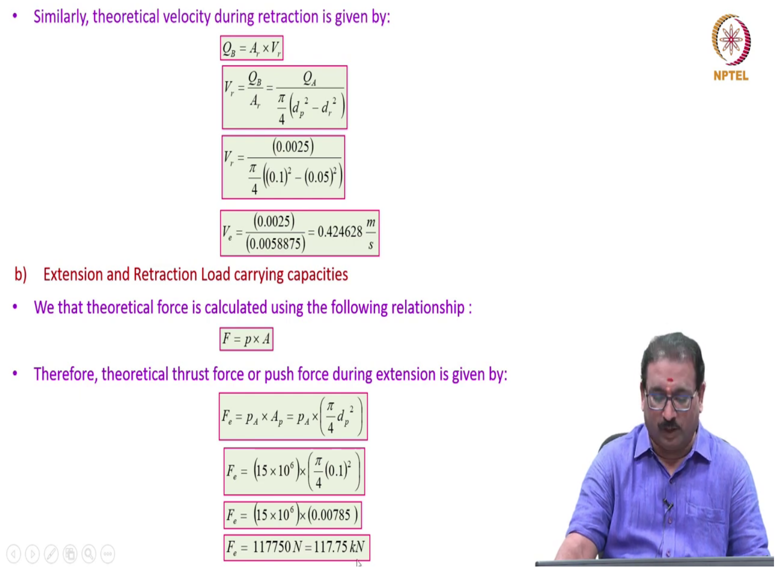

Similarly, the theoretical velocity during the retraction, be careful here Q B equal to A r into V r, then V r equal to Q B by A r, A r area here is a pi by 4 d p square minus d r square. Please understand friends this is very important. Then substitute all the values you may get V equal to 0.4246 meters per second.

Now, we will see the extension and retraction load carrying capacity. Already we know that the general equation for the theoretical force is F equal to p into A correct. Now, we want the theoretical thrust force or a push force during the extension is given by F e equal to p A into A p, A p equal to pi by 4 d p square. Substitute all the values, we may get F e equal to 117.75 kilo Newton.

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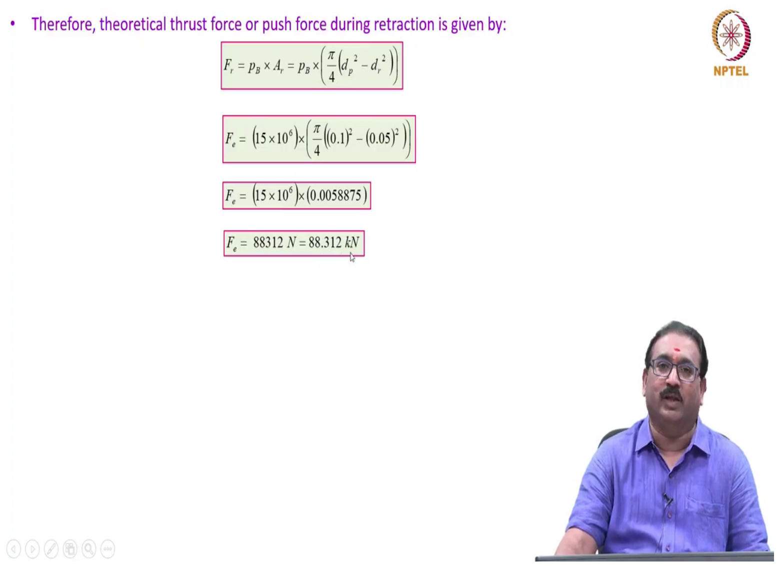

Similarly, the theoretical thrust force or a push force during the retraction. Please careful here pi by 4 d p square minus d r square as I have told you. Substitute all the values, and finally, we will get here how much? 88.312 kilo Newton. Now, we will see one more problem.

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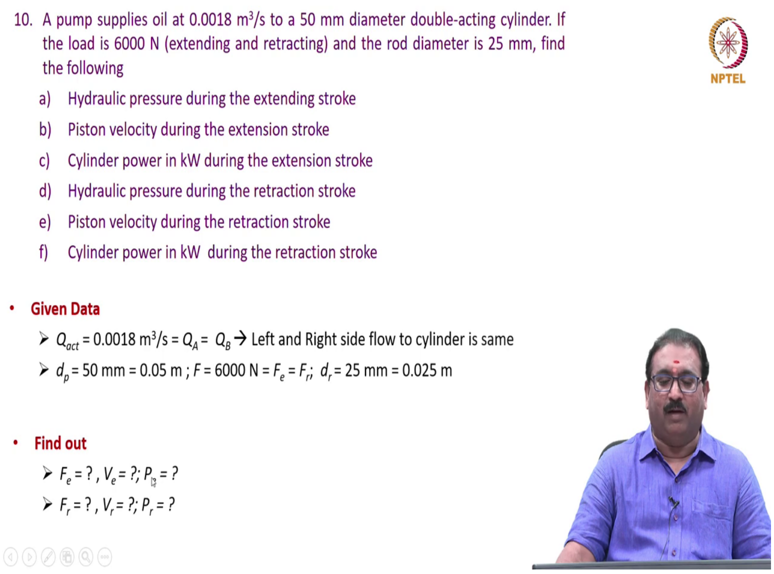

A pump supplies oil at 0.0018 m cube per second to 50 mm diameter double-acting cylinder. If the load is 6000 Newton extending and retracting same load, rod diameter is 25 mm, find the following. Hydraulic pressure during the extension stroke, piston velocity during the extension stroke, cylinder power in kilo watt during the extension stroke, hydraulic pressure during the retraction stroke, piston velocity during the retraction stroke, cylinder power in kilo watt during the retraction stroke.

Let us will begin by listing the given data. The Q actually is given which is at the both side same left and right-side. And d p is given piston diameter 50 mm convert into meter. Then force is given 6000 Newton both extension and retraction. Then rod diameter is given; convert into meter. Keep it same all same units. Then find out we want to find out the F e, V e, and the power in kilo watt. Similarly, for the retraction same parameter.

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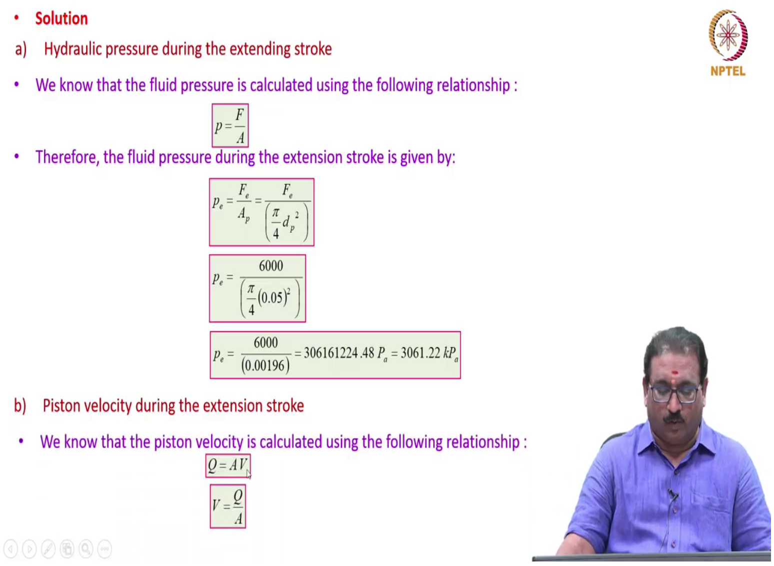

Now, already we know that friends, hydraulic pressure during the extension is given by p equal to F by A general equation it is. Now, for the extension is p e extension F e by A p, F e by pi by 4 d p square. Substitute, all the values you get you may get 3061.22 kilo Pascal. Similarly, the piston velocity during the extension is following the general equation Q equal to A V, we want V, V equal to Q by A. You remember like this.

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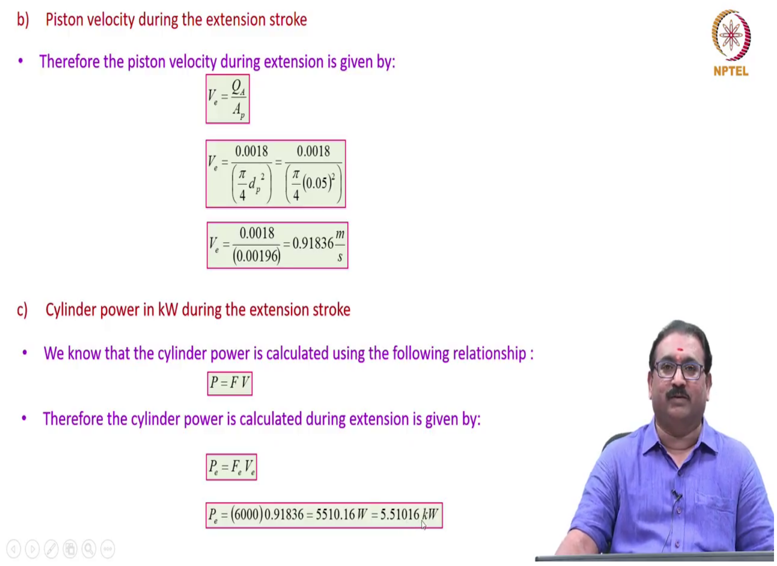

Similarly, you will see now the piston velocity during the extension stroke V e equal to Q A by A p. V e equal to substitute all the given values we may get 0.91836 meters per second. Now, we will move on to the c, cylinder power in kilo watt during the extension stroke.

Already we know that the general equation p equal to F into V. Now, therefore, the cylinder power is calculated during the extension is P e equal to F e into V e; capital P it is. Pressure, I am using always small p; capital P is for the power during the extension. Substitute all the values, you will get 5.51016 kilo watt.

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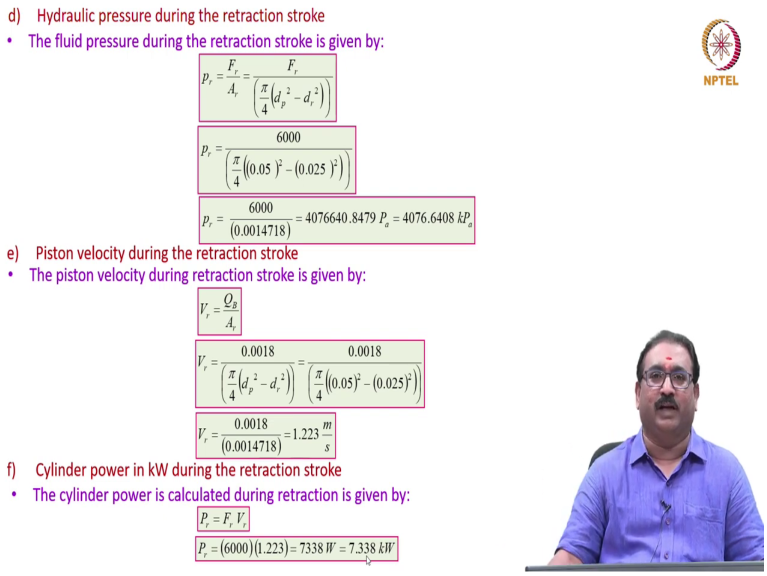

Now, similarly, we have to calculate all the parameter above for the retraction stroke very quickly. Here please careful friends here the pressure at the retraction pi by 4 d p square minus d r square the rod side area.

Substitute all the values you will get 4076.6408 kilo Pascal. Velocity again V r equal to Q B by A r. Everything is same here A r equal to pi by 4 d p square d r square. Substitute all the values, then you will get the velocity during the retraction is 1.223 meters per second.

Similarly, the power, power is P r retraction equal to F r into V r. Substitute all the values, you will get 7.338 kilo watt. Very simple friends you will understand the physics behind it, remember the formula, substitute the values. But be careful for the units that is a very important things.

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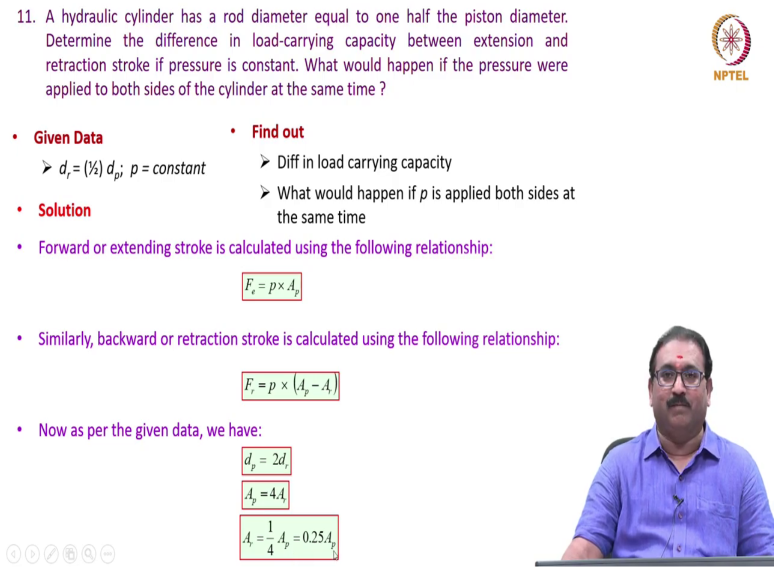

One more problem we will see. A hydraulic cylinder has a rod diameter equal to one-half the piston diameter. Determine the difference in load carrying capacity between the extension and a retraction stroke if pressure is constant. What would happen if the pressure were apply to both side of the cylinder at the same time?

You will see here the many hidden data are there, everything they are given. Here pressure is given, diameter of the piston is given, diameter of the piston rod is given, but in the terms of the sentences very careful. Now, d r – rod area is half the d p, then p equal to constant. Now, we have to find out the difference in load carrying capacity meaning F extension minus F retraction you have to find out.

Similarly, what would happen if p is applied to both the sides, same side, how to attempted this? Forward or a extending stroke already we know that is calculated using the following relationship F e equal to p into A p correct. Similarly, the return stroke or a backward stroke F r equal to p into A p minus A r.

Now, as per the given data d p equal to what they are given? d p equal to 2 times the d r. So, A p equal to 4 times A r. Now, A r equal to what it is? 1 by 4 A p, 1 by 4 equal to 0.25 A p.

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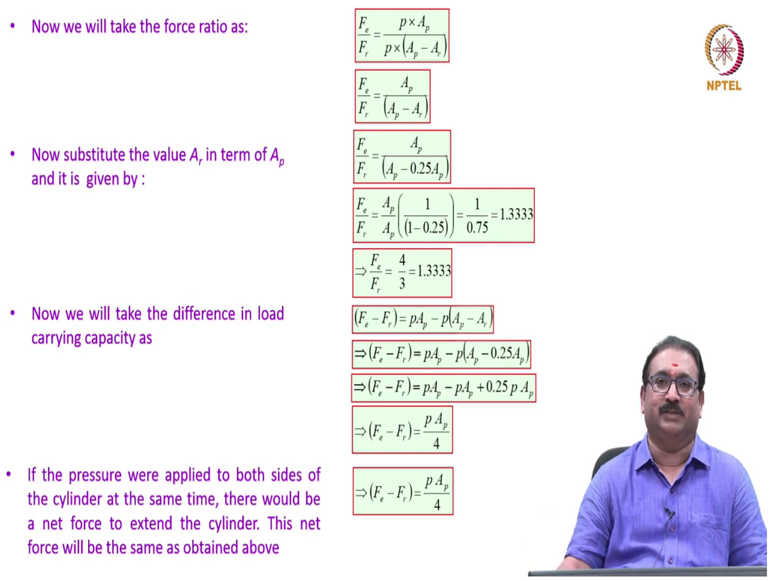

Now, we will take the force ratio, F e by F r extension force by retraction force p into A p, p A p minus A r. p, p get cancel. I may get A p by A p minus A r. Now, we will see friend now substitute the value of A r in terms of p already we know that A r equal 2.25 times A p. Now, you will take A p outside, then you may get A p, A p get cancels, 1 divided by 0.75 is equal to 1.333. Then what is a meaning here? F e by F r equal to 4 by 3, this is 1 by 0.75 equal to 4 by 3 which is nothing but same.

Now, we will take the difference in load carrying capacity. What is a load carrying; F e minus F r. What is a F e for extension? p into A p. Retraction is p into A p minus A r. Now, what we will do? F e minus F r p into A p. What I am doing? Again, I am substituting A r equal to 0.25 A p. Now, we will what we will do? Expand this friends. Then you will see p into A p minus p into A p get cancels. Now, what I will get? I am getting 0.25 p into A p. 0.25 means what it is? 1 by 4, 1 by 4 into p in to A p.

So, if the pressure were applied to both sides of the cylinder at the same time, there would be a net force to extend the cylinder, this net force will be same as the above meaning F e minus F r equal to one-fourth into p into A p very very simple it is. You have to understand the physics in the problem how to arrive it like this.

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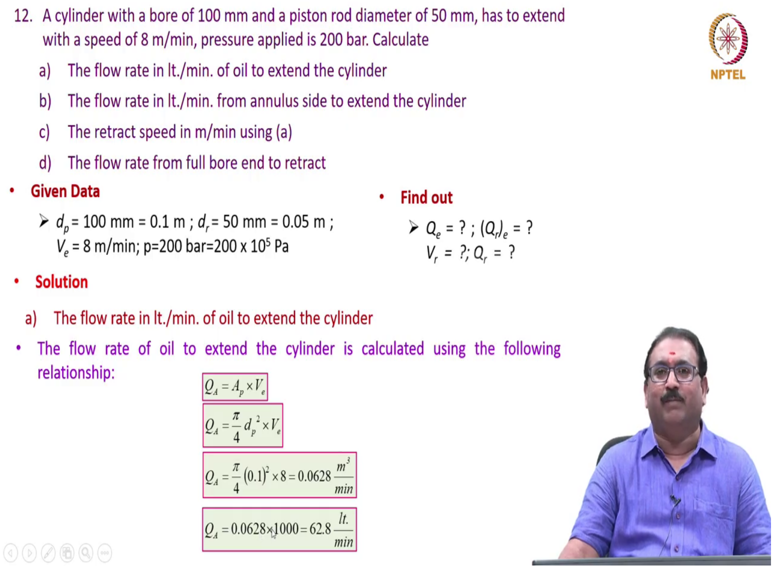

Now, let us we will move onto one more problem. A cylinder with a bore of 100 mm and a piston rod diameter of 50 mm; d p is given, d r is given, has to extend with the speed velocity is given 8 meters per minute, pressure applied p is given 200 bar. You will convert into Pascal by multiplying 10 to the power of 5.

Calculate the flow rate in liters per minute of oil to extend the cylinder, the flow rate in liters per minute from annulus side to extend the cylinder, same time annuals side while extending velocity you have to take there, extending. Then third one is the retracting speed in meters per minute he want, using a the same flow you will take for the retraction. The flow rate from full bore end to retract, how much it is?

Now, the given data d p is given as I have told you, d r is given, V e is given, p is given, convert into same unit – SI units, easy for you. Then you have to find out Q e, Q r during extension, V r and Q r. Solution: The flow rate in liters per minute of oil to extend the cylinder, how to do it?

The flow rate already we during the extension is Q p equal to A p into V e. Now, Q A equal to A p means pi by 4 d p square into V e during extension. All the parameters are given. Substitute the values, you will get 62.8 liters per minute. But we will see here friends, you will get m cube per minute, then converted into liters per minute by multiplying the 1000.

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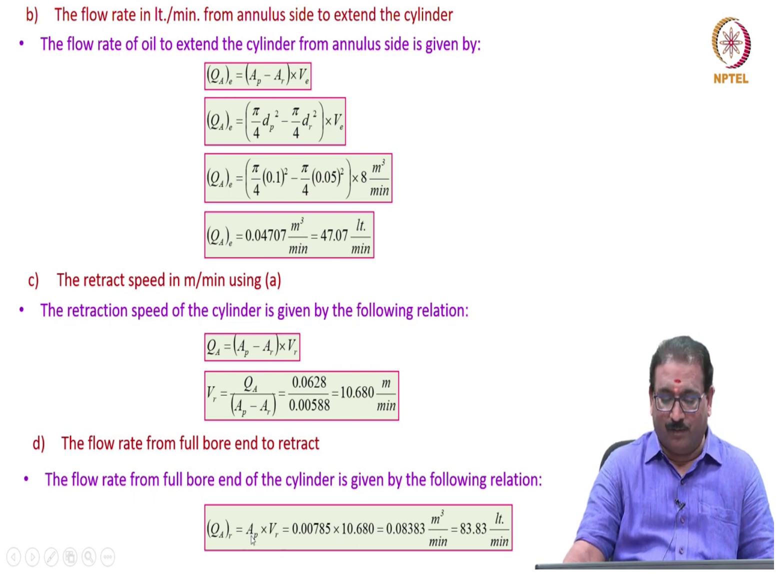

Similarly, the flow rate in liters per minute from annulus side to extension. Annuals side we will see A p minus A r into velocity for the extension you have to take. Substitute all the value, pi by 4 d p square minus pi by 4 d r square into V e. Substitute all the values, you will get the 47.07 liters per minute from the annulus side.

Then retracting speed, retracting speed in meters per minute using the a – meaning pump flow you have to take it will go to the raw data. So, the retraction speed of the cylinder is given by Q A equal to A p minus A r into V r retractions speed we have to calculate now. Then V r equal to what? Q A divided by A p minus A r. This Q A is as in a they told no that is a pump flow that is you will take the pump flow. Then you will get meters per minute.

The flow rate from full bore end to retract. This is given by Q A r equal to A p into V r. Here I am calculating V r, you will take here to multiply the A p from where it is full bore end that is why I am keeping A p here, then you will get 83.83 liters per minute.

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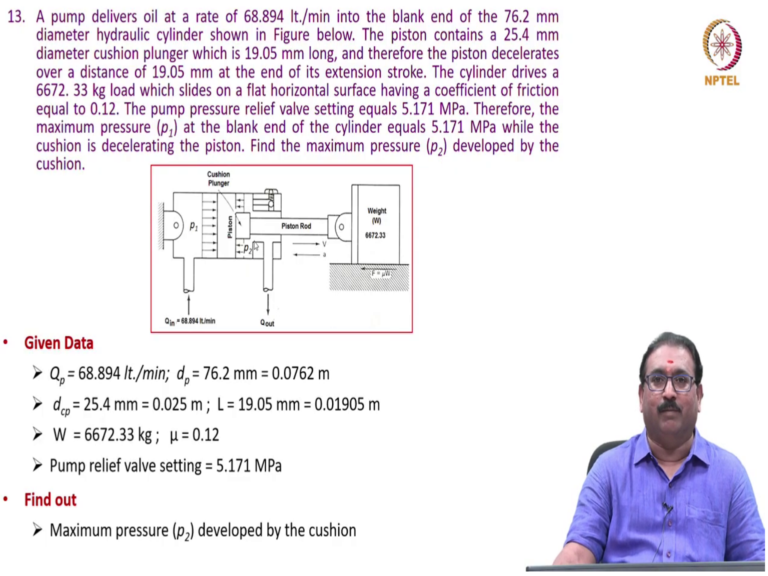

Quickly, we will see one more problem on the cylinder cushioning. Quickly, I will give you the some glimpse how to solve this problem. Then be careful you already know the cushioning to avoid the sudden load or shock load on the end caps. The problem is like this. A pump delivers oil at a rate of 68.894 liters per minute into the blank end of the 76.2 mm diameter hydraulic cylinder shown in figure below.

Here the hydraulic cylinder is shown. This is a head side, in which the pump flow is entering here and this diameter is the piston diameter which is given. The piston contains a 25.4 mm diameter cushion plunger – this plunger cushion plunger is there now, the cushion diameter is given as 25.4; and the length of the cushioning is given as 19.05 mm. And therefore, the piston decelerate over a distance of 19.05, because it is a length of the cushion mm at the end of its extension stroke.

The cylinder drives a 6672.33 kg load which slides on a horizontal surface having a coefficient of friction equal to 0.12 mu value is given. The pump pressure relief valve setting equals 5.171 mega Pascal. Therefore, the maximum pressure p 1 at the blank end of the cylinder equals same pump pressure correctly the 5.171 while the cushioning is decelerating the piston. Find the maximum pressure p 2 here developed by the cushioning.

You will see here friends, the coefficient of friction is there here which is opposing the load moment F equal to mu into W. Here I am taking some of the parameter p 1 is at the head side pressure, p 2 is at the rod side pressure, the velocity is given taken as V, acceleration is taken as a.

Now, as we know these are the given data Q p is given, d p is given, d c p meaning the diameter of the cushioning plunger is given, the length of the cushioning is given, W is given, and mu is given, and a pump relief valve setting. This is nothing but the our maximum PRV settings. Then what is our objective? Objective is to find out the p 2 developed during the developed by the cushion, how much it is.

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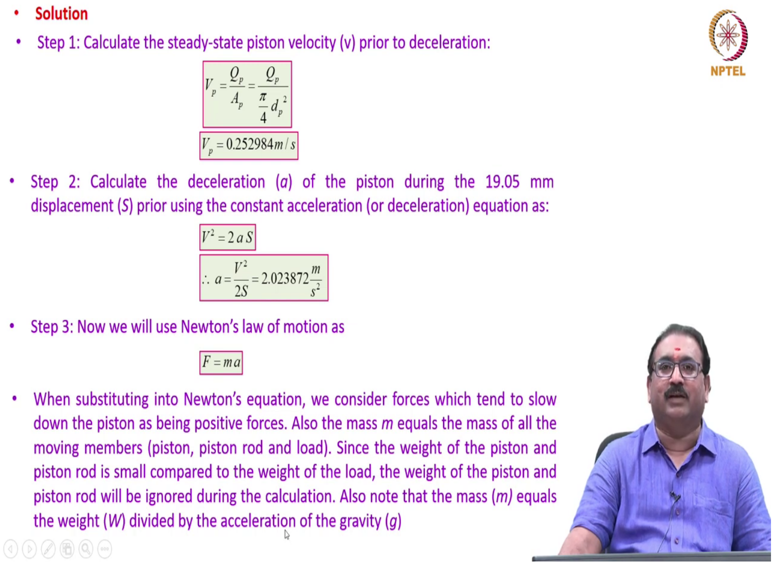

For this, I will quickly I will give you the idea how to do it now we will calculate the steady state piston velocity V prior to the deceleration. Already we know that Q equal to a V relation, then V p equal to Q p by A p, Q p by pi by 4 d p square. Now, substituting all the values, all the values are given in the same unit we will substitute, you will get the V p equal to 0.252984 meters per second.

So, next step is calculate the deceleration that is the a of the piston during the 19.05 mm displacement. Prior using the constant acceleration or deceleration equation as V square equal to 2 a S, then we want a then from this equation a equal to V square by 2 s. Substitute all the values are given, you will get 2.023872 meters per second square.

Step 3 now we will use the Newton's law of motion F equal m into a. Here when substituting into the Newton's equation, we consider the forces which will tend to slow down the piston moment as being the positive forces. Also, the mass m equals the mass of all the moving members. What are the moving member? Piston is moving, piston rod is moving, and the load is moving.

Since the weight of the piston and the piston rod is small compared to the weight of the load, the weight of the piston and piston rod will be ignored during the calculation. Also note that the mass m equals the weight because it given in kg divided by the acceleration of the gravity.

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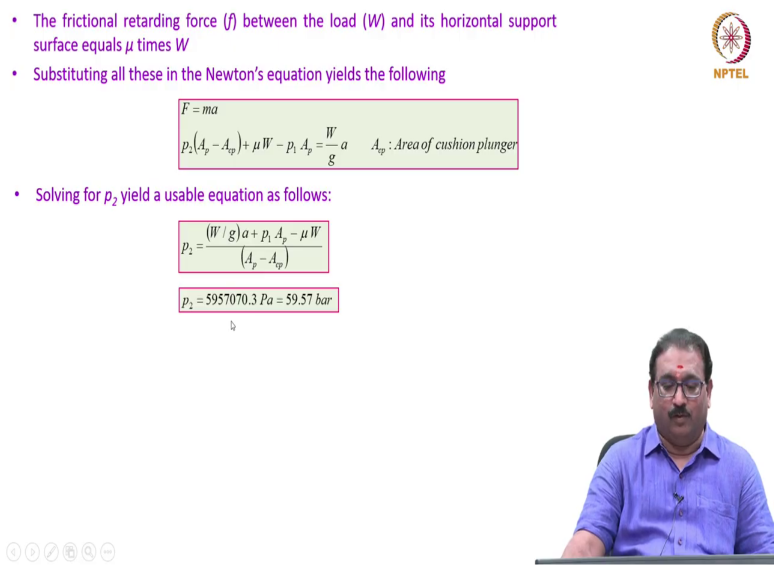

Keeping in mind these things, next we will move on to the also you will remember friends the frictional force F between the load and its horizontal support surface is mu times W that is why in the figure they are given F equal to mu into W, which is opposing the moment. Substituting all the equation in the Newton's equation F equal to m into a, F is the force total force. What is that p 2 into A p minus c p plus mu W minus because it is p 1 by A p equal to W by g into a, same.

Now, solving for the p 2, yields the usable equation as p 2 equal to W by g into a plus p 1 A p minus mu W divided by A p minus A c p you will get it from making the equations. Now, substitute all the values, you will get p 2 equal to 59.57 bar. Very simple friends, but be careful while substituting all the units in the same.

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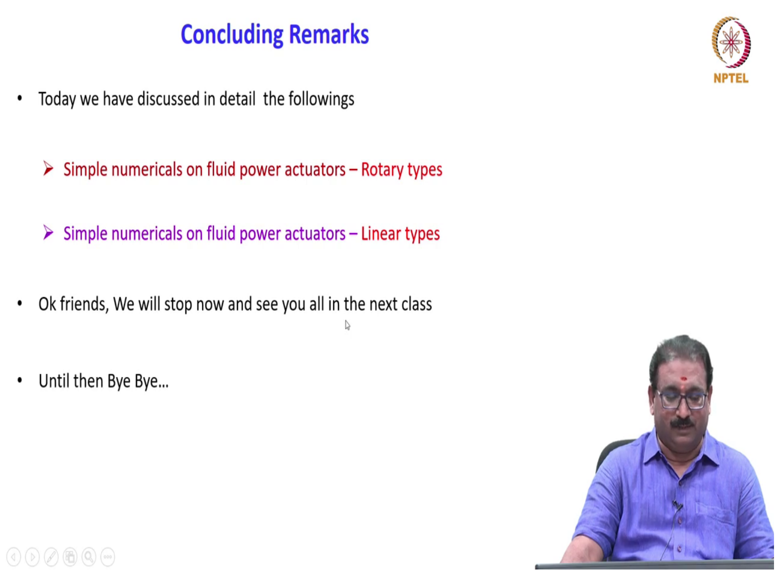

Now, I will conclude today's lecture. Today we have discussed in detail the followings simple numericals on fluid power actuators, rotary actuators we have seen. Similarly, we have seen the simple numericals on the linear types of actuator. Ok friends, we will stop now, and see you all in the next class. Until then bye, bye.

Thank you one and all for your kind attention. [FL]