

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

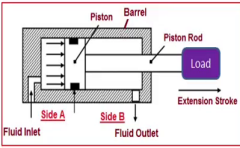
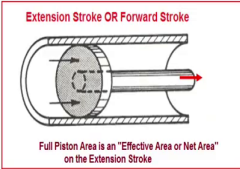
My name is Somashekhar, course faculty for this course.

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Recap **Cylinders : Force, Velocity and Power**



- Referring to Figure below: Theoretical thrust force or a push force is calculated using the following relations

Theoretical thrust force or push force during extension

$$F_e = p_A \times A_p = p \times \left(\frac{\pi}{4} d_p^2 \right)$$

Where d_p is diameter of the piston
 p_A is the fluid pressure at side A

Theoretical velocity during extension is calculated using the following relationship


$$Q_A = A_p \times V_e$$

$$V_e = \frac{Q_A}{A_p}$$

Where A_p is piston head side area
 V_e is the velocity of piston during extension
 Q_A is the volumetric flow rate at side A

Power during extension, $P_e = \text{Force} \times \text{Velocity} = F_e \times V_e$

$$P_e = (p_A \times A_p) \times \left(\frac{Q_A}{A_p} \right) = p_A \times Q_A \quad (1)$$



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.

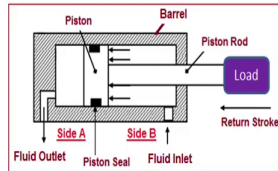
The basic is this. As we know already here I have shown the figure theoretical push force or a thrust force is calculated using the following equations. You see friends here it is a double acting single rod cylinder. To push this load, the pump port is open to the side A. And whatever the fluid is at 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 $\frac{\pi d^2}{4}$ square piston area. Similarly, the theoretical velocity we are calculating the simple equation the Q equal to $A V$ here we want the $V = \frac{Q}{A_p}$ 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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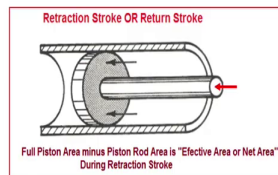
- Referring to Figure below: Theoretical tension force or a pull force is calculated using the following relations



Theoretical tension force OR pull force during retraction is given by

$$F_r = p_B \times A_r = p_B \times \left(\frac{\pi}{4} (d_p^2 - d_r^2) \right)$$

Where d_p is diameter of the piston
 d_r piston rod diameter &
 p_B is the fluid pressure at side B



Theoretical velocity during retraction stroke is calculated using the following relationship

$$Q_B = A_r \times V_r$$

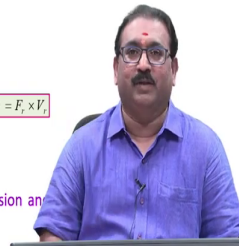
$$V_r = \frac{Q_B}{A_r}$$

Where A_r is piston rod side area
 V_r is the velocity of piston during retraction
 Q_B is the volumetric flow rate at side B

Power during retraction, $P_r = \text{Force} \times \text{Velocity} = F_r \times V_r$

$$P_r = (p_B \times A_r) \times \left(\frac{Q_B}{A_r} \right) = p_B \times Q_B \quad (2)$$

- Comparing the power equations, we can conclude that the power during extension and retraction strokes are the same.



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 π 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_B into A_r Q_B 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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9. An 10 cm hydraulic cylinder has a 5 cm piston rod and receives flow of 100 lt/min at 12 MPa, find the followings:
- a) Extension and Retraction Speeds and b) Extension and Retraction Load carrying capacities
- **Given Data**
 - $d_p = 10 \text{ cm} = 0.1 \text{ m}$; $d_r = 5 \text{ cm} = 0.05 \text{ m}$;
 - $Q_{\text{act}} = 100 \text{ lt./min} = (100/1000 \times 60) 0.0025 \text{ m}^3/\text{s} = Q_A = Q_B$
 - Left and Right side flow to cylinder is same; $p = 12 \text{ MPa}$
 - **Find out**
 - $V_e = ?$ and $V_r = ?$;
 - F_e and F_r



- **Solution**
- a) **Extension and Retraction Speeds**
- We know that theoretical velocity is calculated using the following relationship :
- Therefore, theoretical velocity during extension is given by :

$$Q = A \times V$$

$$Q_A = A_p \times V_e$$

$$V_e = \frac{Q_A}{A_p} = \frac{Q_A}{\frac{\pi}{4} d_p^2}$$

$$V_e = \frac{(0.0025)}{\frac{\pi}{4} (0.1)^2}$$

$$V_e = \frac{(0.0025)}{(0.00785)} = 0.3184 \frac{\text{m}}{\text{s}}$$



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, theoretical velocity during retraction is given by:

$$Q_B = A_r \times V_r$$
$$V_r = \frac{Q_B}{A_r} = \frac{Q_B}{\frac{\pi}{4}(d_p^2 - d_r^2)}$$
$$V_r = \frac{(0.0025)}{\frac{\pi}{4}((0.1)^2 - (0.05)^2)}$$
$$V_r = \frac{(0.0025)}{(0.0058875)} = 0.424628 \frac{m}{s}$$



b) Extension and Retraction Load carrying capacities

- We that theoretical force is calculated using the following relationship :

$$F = p \times A$$

- Therefore, theoretical thrust force or push force during extension is given by:

$$F_e = p_d \times A_p = p_d \times \left(\frac{\pi}{4} d_p^2\right)$$
$$F_e = (15 \times 10^6) \times \left(\frac{\pi}{4} (0.1)^2\right)$$
$$F_e = (15 \times 10^6) \times (0.00785)$$
$$F_e = 117750 \text{ N} = 117.75 \text{ kN}$$



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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- Therefore, theoretical thrust force or push force during retraction is given by:

$$F_r = p_s \times A_r = p_s \times \left(\frac{\pi}{4} (d_p^2 - d_r^2) \right)$$

$$F_r = (15 \times 10^6) \times \left(\frac{\pi}{4} ((0.1)^2 - (0.05)^2) \right)$$

$$F_r = (15 \times 10^6) \times (0.0058875)$$

$$F_r = 88312 \text{ N} = 88.312 \text{ kN}$$



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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10. A pump supplies oil at $0.0018 \text{ m}^3/\text{s}$ to a 50 mm diameter double-acting cylinder. If the load is 6000 N (extending and retracting) and the rod diameter is 25 mm, find the following
- Hydraulic pressure during the extending stroke
 - Piston velocity during the extension stroke
 - Cylinder power in kW during the extension stroke
 - Hydraulic pressure during the retraction stroke
 - Piston velocity during the retraction stroke
 - Cylinder power in kW during the retraction stroke



• **Given Data**

- $Q_{\text{act}} = 0.0018 \text{ m}^3/\text{s} = Q_A = Q_B \rightarrow$ Left and Right side flow to cylinder is same
- $d_p = 50 \text{ mm} = 0.05 \text{ m}$; $F = 6000 \text{ N} = F_e = F_r$; $d_r = 25 \text{ mm} = 0.025 \text{ m}$

• **Find out**

- $F_e = ?$, $V_e = ?$; $P_e = ?$
- $F_r = ?$, $V_r = ?$; $P_r = ?$



A pump supplies oil at 0.0018 m^3 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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- **Solution**

a) Hydraulic pressure during the extending stroke

- We know that the fluid pressure is calculated using the following relationship :

$$p = \frac{F}{A}$$

- Therefore, the fluid pressure during the extension stroke is given by:

$$p_e = \frac{F_e}{A_p} = \frac{F_e}{\left(\frac{\pi d_p^2}{4}\right)}$$

$$p_e = \frac{6000}{\left(\frac{\pi (0.05)^2}{4}\right)}$$

$$p_e = \frac{6000}{(0.00196)} = 306161224.48 \text{ Pa} = 3061.22 \text{ kPa}$$

b) Piston velocity during the extension stroke

- We know that the piston velocity is calculated using the following relationship :

$$Q = AV$$

$$V = \frac{Q}{A}$$



Now, already we know that friends, hydraulic pressure during the extension is given by $p = \frac{F}{A}$ general equation it is. Now, for the extension is $p_e = \frac{F_e}{A_p}$, F_e by F by $\frac{\pi d_p^2}{4}$. 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 $Q = AV$, we want V , $V = \frac{Q}{A}$. You remember like this.

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b) Piston velocity during the extension stroke

- Therefore the piston velocity during extension is given by:

$$V_e = \frac{Q_e}{A_p}$$

$$V_e = \frac{0.0018}{\left(\frac{\pi d_p^2}{4}\right)} = \frac{0.0018}{\left(\frac{\pi (0.05)^2}{4}\right)}$$

$$V_e = \frac{0.0018}{(0.00196)} = 0.91836 \frac{m}{s}$$

c) Cylinder power in kW during the extension stroke

- We know that the cylinder power is calculated using the following relationship :

$$P = F V$$

- Therefore the cylinder power is calculated during extension is given by:

$$P_e = F_e V_e$$

$$P_e = (6000) 0.91836 = 5510.16 W = 5.51016 kW$$



Similarly, you will see now the piston velocity during the extension stroke V_e equal to Q_e 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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d) Hydraulic pressure during the retraction stroke

- The fluid pressure during the retraction stroke is given by:

$$P_r = \frac{F_r}{A_r} = \frac{F_r}{\left(\frac{\pi}{4}(d_p^2 - d_r^2)\right)}$$

$$P_r = \frac{6000}{\left(\frac{\pi}{4}((0.05)^2 - (0.025)^2)\right)}$$

$$P_r = \frac{6000}{(0.0014718)} = 4076640.8479 \text{ Pa} = 4076.6408 \text{ kPa}$$

e) Piston velocity during the retraction stroke

- The piston velocity during retraction stroke is given by:

$$V_r = \frac{Q_B}{A_r}$$

$$V_r = \frac{0.0018}{\left(\frac{\pi}{4}(d_p^2 - d_r^2)\right)} = \frac{0.0018}{\left(\frac{\pi}{4}((0.05)^2 - (0.025)^2)\right)}$$

$$V_r = \frac{0.0018}{(0.0014718)} = 1.223 \frac{\text{m}}{\text{s}}$$

f) Cylinder power in kW during the retraction stroke

- The cylinder power is calculated during retraction is given by:

$$P_r = F_r V_r$$

$$P_r = (6000)(1.223) = 7338 \text{ W} = 7.338 \text{ kW}$$



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 P_r by F_r divided by A_r which is $\frac{\pi}{4}(d_p^2 - d_r^2)$.

Substitute all the values you will get 4076.6408 kilo Pascal. Velocity again V_r equal to Q_B divided by A_r . Everything is same here A_r equal to $\frac{\pi}{4}(d_p^2 - d_r^2)$. 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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11. A hydraulic cylinder has a rod diameter equal to one half the piston diameter. Determine the difference in load-carrying capacity between extension and retraction stroke if pressure is constant. What would happen if the pressure were applied to both sides of the cylinder at the same time ?



- **Given Data**
 - $d_r = (\frac{1}{2}) d_p$; $p = \text{constant}$
- **Solution**
- Forward or extending stroke is calculated using the following relationship:

$$F_e = p \times A_p$$

- Similarly, backward or retraction stroke is calculated using the following relationship:

$$F_r = p \times (A_p - A_r)$$

- Now as per the given data, we have:

$$d_r = \frac{1}{2} d_p$$

$$A_r = \frac{1}{4} A_p$$

$$A_r = \frac{1}{4} A_p = 0.25 A_p$$



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 $F_{\text{extension}}$ minus $F_{\text{retraction}}$ 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 as:

$$\frac{F_e}{F_r} = \frac{p \times A_p}{p \times (A_p - A_r)}$$

$$\frac{F_e}{F_r} = \frac{A_p}{(A_p - A_r)}$$

- Now substitute the value A_r in term of A_p and it is given by :

$$\frac{F_e}{F_r} = \frac{A_p}{(A_p - 0.25A_p)}$$

$$\frac{F_e}{F_r} = \frac{A_p}{A_p (1 - 0.25)} = \frac{1}{0.75} = 1.3333$$

$$\Rightarrow \frac{F_e}{F_r} = \frac{4}{3} = 1.3333$$

- Now we will take the difference in load carrying capacity as

$$(F_e - F_r) = pA_p - p(A_p - A_r)$$

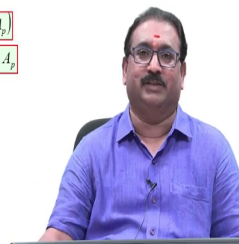
$$\Rightarrow (F_e - F_r) = pA_p - p(A_p - 0.25A_p)$$

$$\Rightarrow (F_e - F_r) = pA_p - pA_p + 0.25pA_p$$

$$\Rightarrow (F_e - F_r) = \frac{pA_p}{4}$$

- 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 the same as obtained above

$$\Rightarrow (F_e - F_r) = \frac{pA_p}{4}$$



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 0.25 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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12. A cylinder with a bore of 100 mm and a piston rod diameter of 50 mm, has to extend with a speed of 8 m/min, pressure applied is 200 bar. Calculate
- The flow rate in lt./min. of oil to extend the cylinder
 - The flow rate in lt./min. from annulus side to extend the cylinder
 - The retract speed in m/min using (a)
 - The flow rate from full bore end to retract



• **Given Data**

➤ $d_p = 100 \text{ mm} = 0.1 \text{ m}$; $d_r = 50 \text{ mm} = 0.05 \text{ m}$;
 $V_e = 8 \text{ m/min}$; $p = 200 \text{ bar} = 200 \times 10^5 \text{ Pa}$

• **Find out**

➤ $Q_e = ?$; $(Q_d)_e = ?$
 $V_r = ?$; $Q_r = ?$

• **Solution**

- The flow rate in lt./min. of oil to extend the cylinder
- The flow rate of oil to extend the cylinder is calculated using the following relationship:

$$Q_d = A_p \times V_e$$

$$Q_d = \frac{\pi}{4} d_p^2 \times V_e$$

$$Q_d = \frac{\pi}{4} (0.1)^2 \times 8 = 0.0628 \frac{\text{m}^3}{\text{min}}$$

$$Q_d = 0.0628 \times 1000 = 62.8 \frac{\text{lt.}}{\text{min}}$$



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 annulus 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 π 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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- b) The flow rate in Lt./min. from annulus side to extend the cylinder
- The flow rate of oil to extend the cylinder from annulus side is given by:

$$Q_{a,e} = (A_p - A_r) \times V_r$$

$$Q_{a,e} = \left(\frac{\pi}{4} d_p^2 - \frac{\pi}{4} d_r^2 \right) \times V_r$$

$$Q_{a,e} = \left(\frac{\pi}{4} (0.1)^2 - \frac{\pi}{4} (0.05)^2 \right) \times 8 \frac{m^3}{min}$$

$$Q_{a,e} = 0.04707 \frac{m^3}{min} = 47.07 \frac{lt.}{min}$$

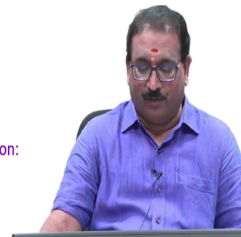
- c) The retract speed in m/min using (a)
- The retraction speed of the cylinder is given by the following relation:

$$Q_a = (A_p - A_r) \times V_r$$

$$V_r = \frac{Q_a}{(A_p - A_r)} = \frac{0.0628}{0.00588} = 10.680 \frac{m}{min}$$

- d) The flow rate from full bore end to retract
- The flow rate from full bore end of the cylinder is given by the following relation:

$$Q_{a,r} = A_p \times V_r = 0.00785 \times 10.680 = 0.08383 \frac{m^3}{min} = 83.83 \frac{lt.}{min}$$



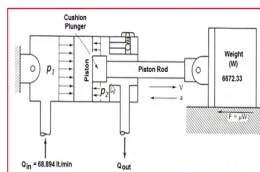
Similarly, the flow rate in liters per minute from annulus side to extension. Annulus side we will see A_p minus A_r into velocity for the extension you have to take. Substitute all the value, pi by 4 d_p square minus pi by 4 d_r square into V_e . Substitute all the values, you will get the 47.07 liters 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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13. A pump delivers oil at a rate of 68.894 lt./min into the blank end of the 76.2 mm diameter hydraulic cylinder shown in Figure below. The piston contains a 25.4 mm diameter cushion plunger which is 19.05 mm long, and therefore the piston decelerates over a distance of 19.05 mm at the end of its extension stroke. The cylinder drives a 6672.33 kg load which slides on a flat horizontal surface having a coefficient of friction equal to 0.12. The pump pressure relief valve setting equals 5.171 MPa. Therefore, the maximum pressure (p_1) at the blank end of the cylinder equals 5.171 MPa while the cushion is decelerating the piston. Find the maximum pressure (p_2) developed by the cushion.



- **Given Data**
 - $Q_p = 68.894 \text{ lt./min}$; $d_p = 76.2 \text{ mm} = 0.0762 \text{ m}$
 - $d_{cp} = 25.4 \text{ mm} = 0.025 \text{ m}$; $L = 19.05 \text{ mm} = 0.01905 \text{ m}$
 - $W = 6672.33 \text{ kg}$; $\mu = 0.12$
 - Pump relief valve setting = 5.171 MPa
- **Find out**
 - Maximum pressure (p_2) developed by the cushion



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 μ 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 μ 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 μ 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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• **Solution**

• Step 1: Calculate the steady-state piston velocity (v) prior to deceleration:

$$V_p = \frac{Q_p}{A_p} = \frac{Q_p}{\frac{\pi d_p^2}{4}}$$
$$V_p = 0.252984 \text{ m/s}$$



• Step 2: Calculate the deceleration (a) of the piston during the 19.05 mm displacement (S) prior using the constant acceleration (or deceleration) equation as:

$$V^2 = 2 a S$$
$$\therefore a = \frac{V^2}{2S} = 2.023872 \frac{\text{m}}{\text{s}^2}$$

• Step 3: Now we will use Newton's law of motion as

$$F = ma$$

• When substituting into Newton's equation, we consider forces which tend to slow down the piston as being positive forces. Also the mass m equals the mass of all the moving members (piston, piston rod and load). Since the weight of the piston and 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 (W) divided by the acceleration of the gravity (g)



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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 π 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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- The frictional retarding force (f) between the load (W) and its horizontal support surface equals μ times W
- Substituting all these in the Newton's equation yields the following



$$F = ma$$

$$p_1(A_p - A_c) + \mu W - p_2 A_p = \frac{W}{g} a \quad A_c : \text{Area of cushion plunger}$$

- Solving for p_2 yield a usable equation as follows:

$$p_2 = \frac{(W/g)a + p_1 A_p - \mu W}{(A_p - A_c)}$$

$$p_2 = 5957070.3 \text{ Pa} = 59.57 \text{ bar}$$

4



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 μ times W that is why in the figure they are given F equal to μ 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 μW 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 μW divided by A_p minus A_c 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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Concluding Remarks



- Today we have discussed in detail the followings
 - Simple numericals on fluid power actuators – Rotary types
 - Simple numericals on fluid power actuators – Linear types
- Ok friends, We will stop now and see you all in the next class
- Until then Bye Bye...



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]