Fluid Machines.

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Tutorial-8.

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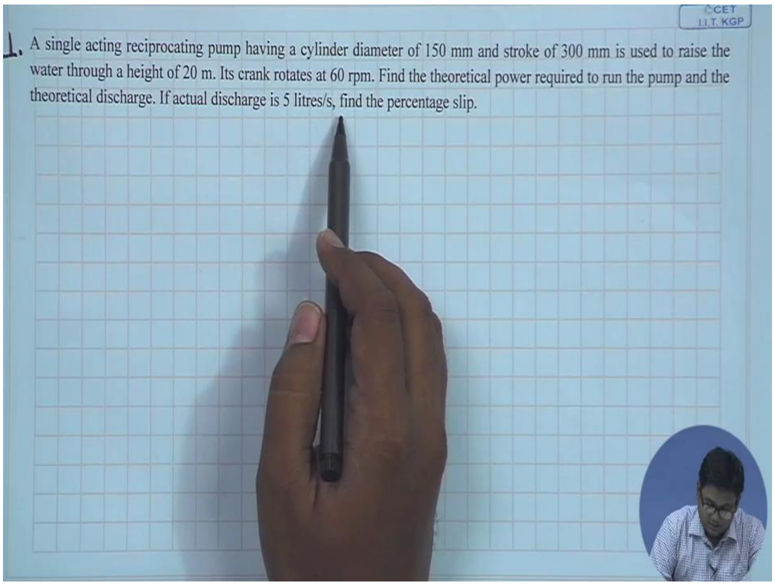

Welcome to the session of the course fluid machines. Today we are going to solve few problems related to reciprocating pumps. So let us start with problem number-one. So the problem statement is given as follows. A single acting reciprocating pump having a cylinder diameter of 150 millimetre and stroke of 300 millimetre is used to raise the water through a height of 20 meter. Its crank rotates at 60 rpm, find the theoretical power required to run the pump and the theoretical discharge. If actual discharge is 5 litres per second, find the percentage slip.

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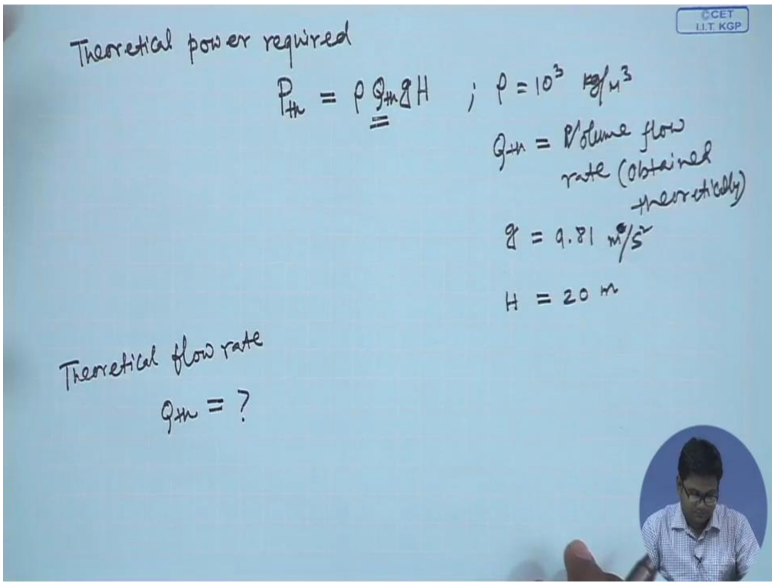

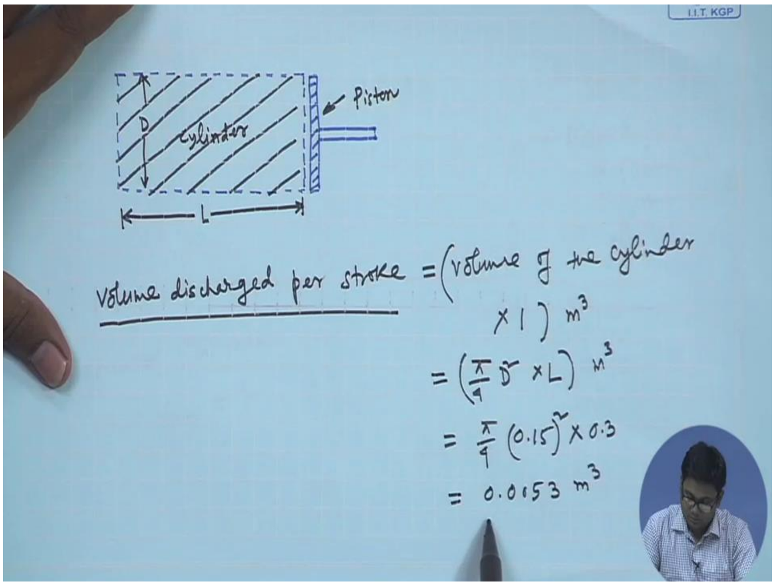

So this is a schematic of the problem, this is the cylinder, this is the piston. This is cylinder diameter D and this is the stroke length L. Now let us 1st note down the important given quantities here. Given quantities are, the cylinder diameter D which is 150 millimetre, stroke length L 300 millimetre, the water is raised through a height of 20 meter, so let us denote that by H equals 20 meter. Crank rotates at a speed of 60 rpm. Another important thing to note here is it is a single acting reciprocating pump.

So single acting reciprocating pump, which means it discharges only once in one rotation. And the actual discharge is given as 50 meter. So QA is actual discharge is 5 metres per second. Now to find the theoretical power required, let us 1st write expression of theoretical power. So theoretical power required better PTH is rho Q theoretical GH. Where rho is the density of water 10 cube KG per metre cube, Q theoretical is the theoretical discharge or the volume flow rate obtained theoretically.

G is the acceleration due to gravity 9.81 metre square per second, sorry metre per second square and H is the height through which water is raised, so each is 20 meter. Now from this relation we can obtain P theoretical or theoretical power required to operate the pump provided we know the theoretical flow rate. So let us 1st find the theoretical flow rate. Theoretical flow rate Q theoretical. Now in this case the pump discharges the whole volume, so go back to the schematic.

So let us, in a 1 stroke, the, this amount of volume will be displaced from the cylinder. So volume discharged per stroke will be volume of the cylinder times the number of reciprocating motions performed in discharge. As it is a single acting reciprocating pump so in this case this will be 1. So the volume discharge per stroke will be nothing but the volume of the cylinder. The volume of the cylinder, that means this is in metre cube, so volume of the cylinder is a cross-sectional area of the cylinder pie by4 D square times the stroke length.

So let us just substitute the quantities from here. So D is 150 millimetre and L is 300 millimetre. So pie by4, in unit, in metre unit we can express this. So this can be obtained as 0.53, 0.0053 metre cube. So theoretically obtained volume discharged per stroke is 0 .0053 metre cube. Now as the rotational or the crank rotates at 60 rpm, so N equals 60. So in this case the reciprocating pump performs 60 strokes per minute or a single stroke per second.

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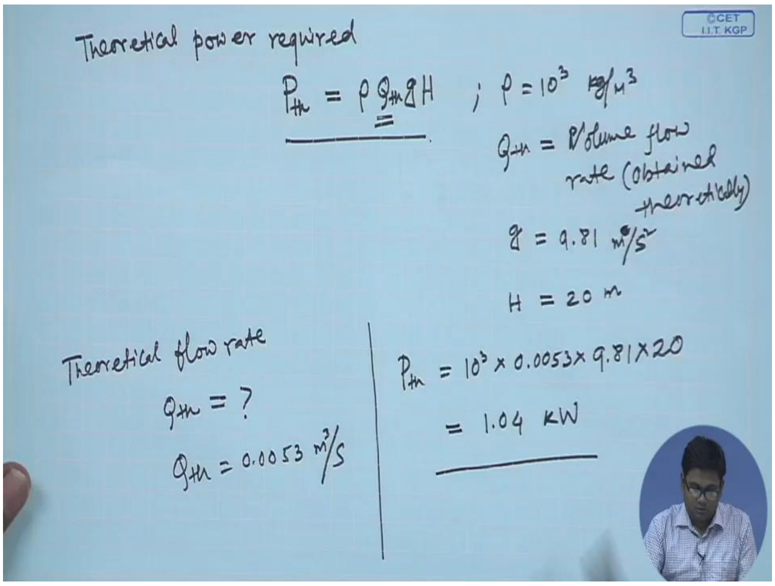

So the volume flow rate, so theoretical volume flow rate will be volume, so one thing to note here is that this much of volume is displaced by single stroke and the reciprocating pump performs 60 strokes per minute or a single stroke per second. So the volume flow rate will be nothing but this meaning time in metre cube per second. So 0.0053 metre cube per second, as N is 60 rpm, which is 1 rps and it is a single acting pump.

So we have found one of the required answers which is the theoretical discharge. Now let us find out the power required. Now theoretical power required is given by this relation. So now we just have to substitute all the quantities. Now we have obtained Q theoretical as 0.0053 metre cube per second. So P theoretical will be rho is 10 cube, Q is 0.0053, G is 9.81 and head developed or the height through which the water is raised is given as 20 meter. So this you can obtain as 1.04 kilowatts.

So theoretical power now we have obtained. The next task is to find out the percentage slip. Now due to slippage, some volume is not discharge. So theoretically found, we have the volume that we have is 0.0053 metre cube per second. So due to leakage, this much of volume will not be discharge through the reciprocating pump. So the slip in this case is the difference in theoretical and actual flow rate and we define slip factor by taking the ratio of this difference with the theoretical flow rate and take the percentage of that.

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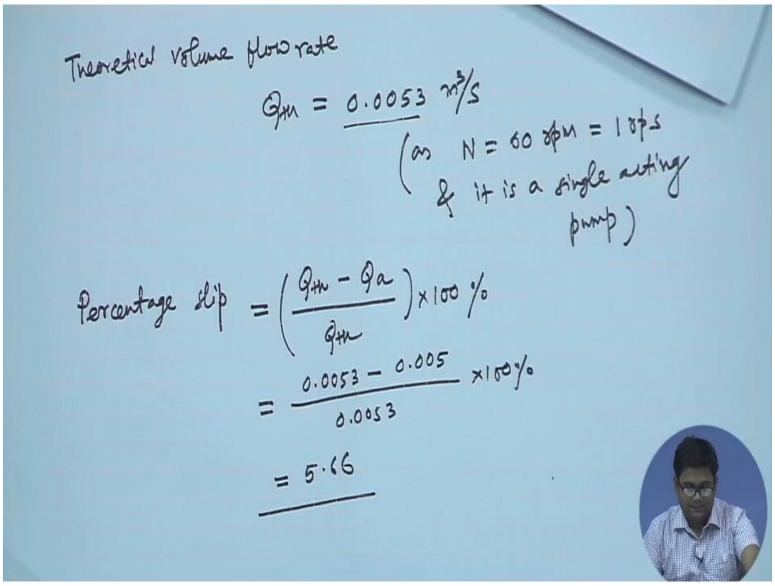

So let us define the slip factor. So percentage slip is defined as theoretical flow rate minus actual flow rate over the theoretical flow rate times 100 percent. So we have obtained theoretical flow rate as 0.0053. Actual flow rate is mentioned in the problem, so actual flow rate is given as 5 litres per second, in metre cube per second that will be 0.005 divided by the theoretical flow rate. So this is 5.66. So percentage of slip is 5.66. So we have obtained all the quantities, the power required, the theoretical discharge and percentage slip.

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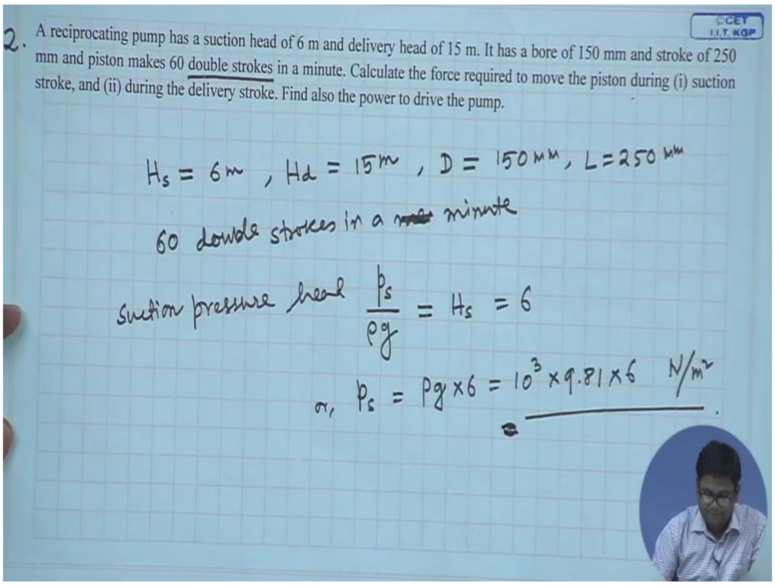

Now we will move onto our 2nd problem which is also related to reciprocating pump. So let us 1st read the problem. Now I reciprocating pump has a suction head of 6 metre and delivery head of 15 metre. It has a bore of 150 millimetre and stroke of 250 millimetre and piston makes 60 double strokes in a minute. Calculate the force required to move the piston during suction stroke and during the delivery stroke. Find also the power required to drive the pump.

So in this case the suction head HS is 6 metres, the delivery head HD is 15 metres, the bore is nothing but the diameter of the cylinder is 150 millimetres and the stroke length is 250 millimetre. And the piston makes 60 double strokes in a minute. So let us note this down, 60 double strokes in a minute. Now we have to find out the force required to move the piston during suction stroke and delivery stroke. Now the suction pressure head, pressure head which is PS by rho G, let us denote suction pressure by PS, so PS by rho G is the suction head which is given as 6 metres.

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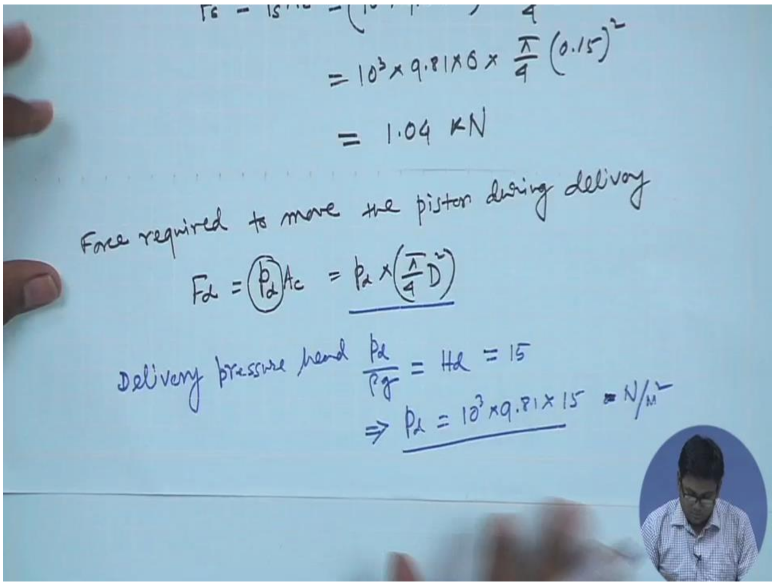

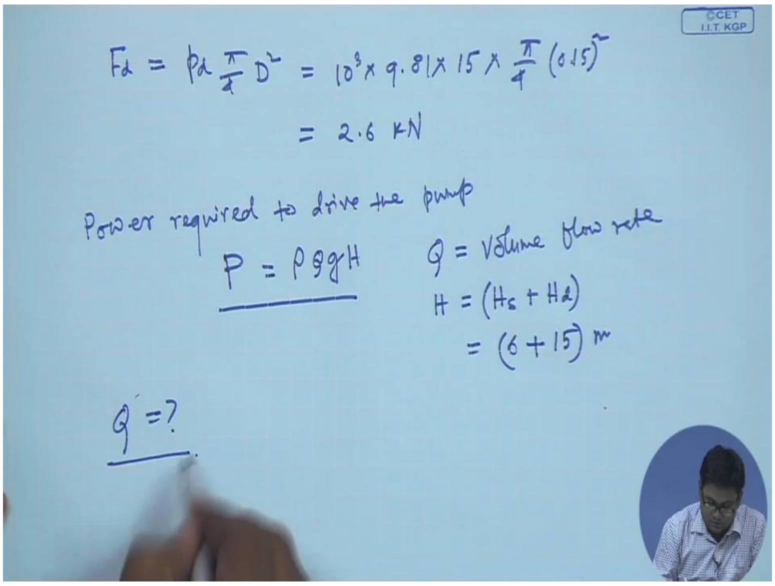

So the suction pressure will be rho G times 6, the density of water 1000 , G 9.81 and 6. So this will be, so this will come in Newton per metre square, so this will be the pressure. Now the force, let us find out the force required. So we have to find the suction stroke, calculate the force required to move the piston during suction stroke. So the force required to move the piston during suction. So the force during suction will be nothing but the pressure times the cross-sectional area of the cylinder.

So the pressure we have, suction pressure we have obtained as this, so let us just substitute here. 10 cube 9.81 times 6, this is the force and the cross sectional area is pie by4 D square. So substitute D here, so bore diameter is given as 150 millimetre, so 0.15 metres, so this you can obtain as 1.04 kilonewton. So this is the required forced to move the piston during suction. Now we have to find out the force required to move the piston during the delivery.

So let us find this out. So force required to move the piston during delivery. This will be nothing but pressure during the delivery and the cross-sectional area. So PD times pie by4 D square, this is the expression. Now let us find out what is the pressure here. Similarly in this case also the delivery pressure head, pressure head PD by rho G is HD which is the delivery head. HD is given in the problem as 15 metre. So from here we can find PD as rho times G times 15, this in Newton per metre square. So let us substitute this pressure in this expression to obtain the force.

So for required to move the piston during delivery will be PD pie by4 D square, PD is 10 cube into 9.81 times 15 pie by4 and D is 0.15 metre. So this you can obtain as 2.6 kilo Newton. Now the next task is to obtain the power required to drive the pump. So the power required to drive the pump, pump P will be rho QG times H, where Q is the volume flow rate, volume flow rate, H is the total head which is the summation of HS and HD. So H will be, HS is given as 6 metre, HD is 15 meter, so this is the total head. Now to obtain the power required, we 1st have to find the volume flow rate Q, what is Q.

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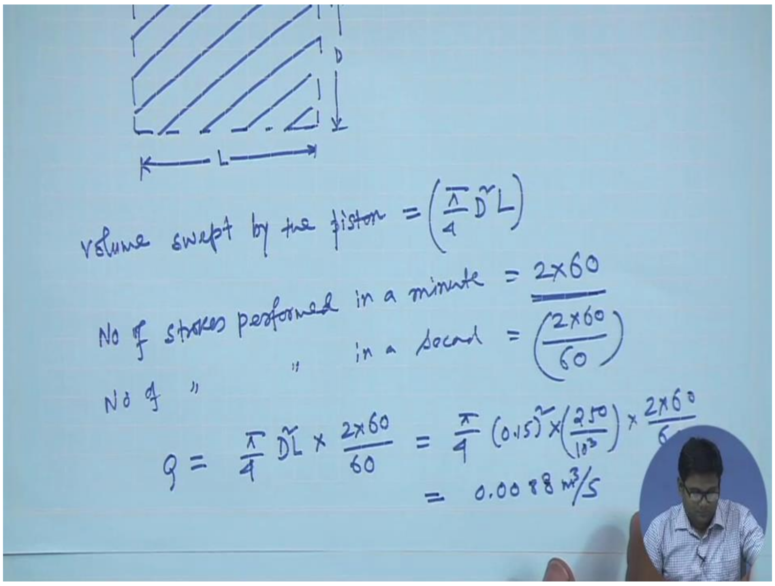

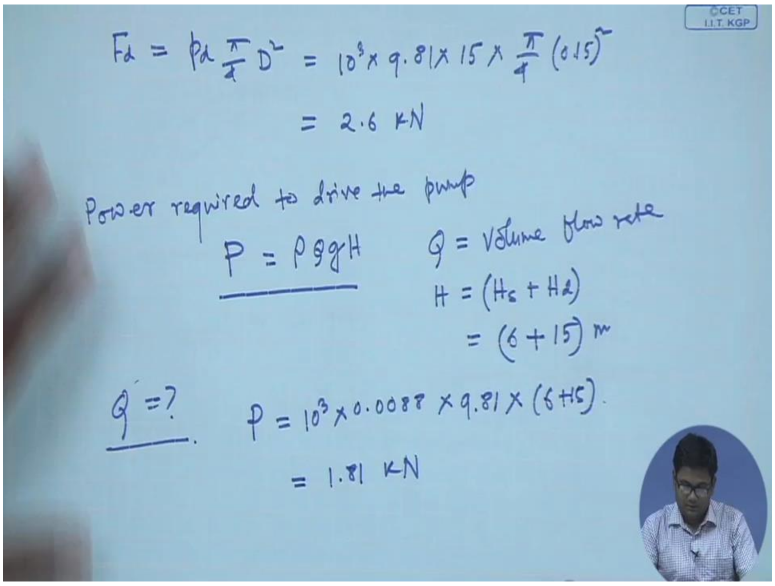

A similar to the previous schematic, let us draw another time. So this is the control volume with bore diameter D and stroke length L. So in this case the volume swept by the piston is this much. So volume swept by the piston is pie by4 D square L. So this much of volume is swept in a single stroke. Now one important thing to note here is that the pump performance 60 double strokes in a minute. So in a minute it pumps, perform 60 times 2, so 120 strokes in one-minute.

That means it performs, so number of, let us note down this, number of strokes performed in a minute is 2 times 60, because this is a double acting pump, so and 60 double cycles mean 2 into 60 times this is the number of strokes performed in a minute. So number of strokes performed in a second will be nothing but 2 times 60 divided by 60. So this is the number of strokes performed per second. So the volume flow rate will be nothing but this volume swept by the piston in a single stroke times this.

So let us substitute all the relevant quantities. This times 2 into 60 by 60. So pie by4 D is 0.15 square, L is given as 250 millimetre, so this metre and 2 into 60 by 60. So this you can obtain as 0.0088 metre cube per second. Now let us substitute this flow rate in the expression of power, so power is rho times Q is now 0.0088, 0.0088 times G 9.81 and H is 6+15. So power is 1.81 kilo Newton, so now we have obtained all the quantity is relevant to this problem. With this I am ending today's tutorial class, thank you.