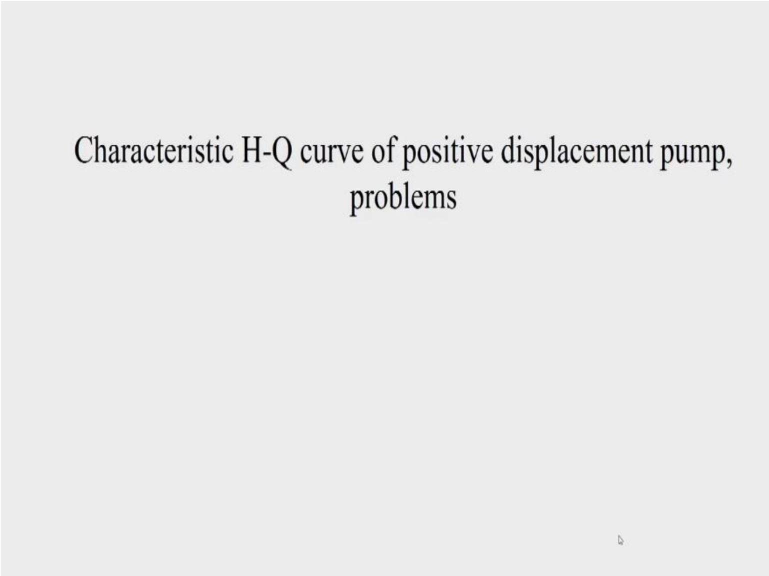
Principle of Hydraulic Machines and System Design
Dr. Pranab K. Mondal
Department of Mechanical Engineering
Indian Institute of Technology, Guwahati

Lecture – 23
Characteristic H-Q curve of positive displacement pump, problems

We will continue our discussion on Principle of Hydraulic Machines and System Design.

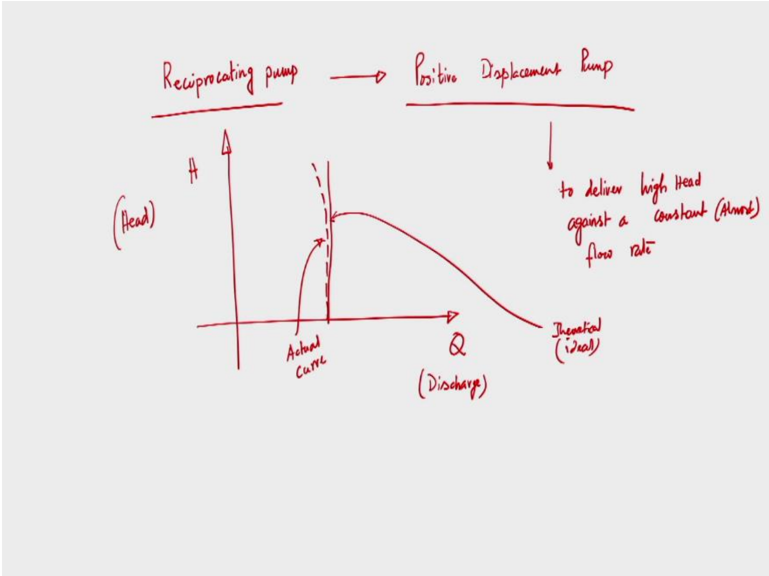
(Refer Slide Time: 00:33)



Today we will talk about the characteristics of HQ curve of a positive displacement pump and we will work out a numerical problem. So, we are discuss about the HQ characteristic curve when we have discussed about the I mean operational principle of the PD pump that are we have taken example the you know working principle of reciprocating pump because, reciprocating pump also a class of you know which falls under the category of PD pump rather Positive Displacement pump.

I said that apart from the reciprocating pump there are many other pumps like screw pump, vane pump, gear pumps, those also you know falls under the category of reciprocating pump is p positive displacement pump, but reciprocating pump also a class of you know positive displacement pumps. So, we are discussing about the HQ curve, but today again we will discuss recapitulate that curve and we will work out a numerical example.

(Refer Slide Time: 01:29)



So, if we recall that normally we have taken example of reciprocating pump, reciprocating pump which is a class of positive displacement pump and we have discussed about the working principle, how this pump works? I mean it sucks you know the pump sucks fluid from the sump, then it discharges just to the delivery tank. And there is you know suction stroke and delivery stroke, and which is connected by a crank and connecting rod mechanism. So, the linear motion of the piston is now is you know created by the you know crank and connecting rod mechanism.

And it also depends upon the pump upon also depends upon the frequency of you know rather rotation of the crank speed. And we have discussed that if we try to draw the HQ curve of a PD pump so, the HQ curve look like this. So, this is the discharge, this is the H; so, this is discharge and this is head.

So, if we try to you know develop the HQ curve for this kind of pump, then how we will get it? We have discuss that; the PD pumps you know positive displacement pumps are this head Q HQ curve is like this that normally this pumps is or this pumps are used this class of pumps are used to deliver high head against a almost constant flow rate constant flow rate. So, this is the characteristics feature of the positive displacement pump.

So, it is normally used to deliver high head against a constant head here remains almost constant. So that means, if I draw the HQ curve the curve like this. So, as I said that this is again so, this is again theoretical one so, this is theoretical rather ideal, but we have discuss that normally whenever it discharges when delivery strokes I mean when piston moves from the open end of the cylinder to the close end of the cylinder.

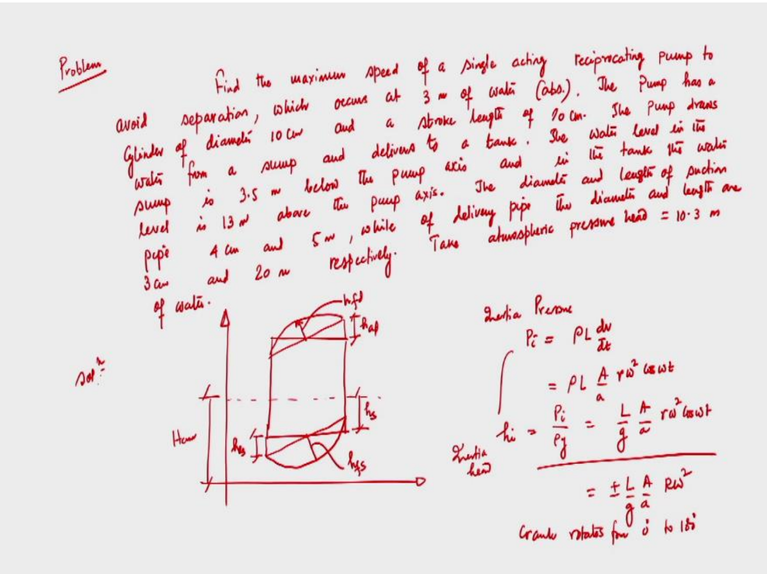
Then, it discharges water to delivery sump and then high pressure develops, because of that high pressure there is a leakage of some amount through the glands. And as a result of which we get actual curve which look likes this. So, this is the actual curve so, this is the actual curve, because of the leakage through glands.

So, this is HQ curve and that is why we have define one efficiency that is called volumetric efficiency, and we have obtained that volumetric efficiency is basically actual discharge by the ideal discharge and then we define one slip factor that is you know there is some amount of leakage. So, $\frac{Q_{th}-Q_{ac}}{Q_{th}}$ we have discussed in the last I mean lecture.

Now another today we will work out one an example today we will work out one example so you know how we can solve a particular numerical problem for reciprocating pump is very important. So, we will take an example now and we will see how we can solve this particular problem and we will write the problem.

And then we will solve the problem considering the theoretical analysis that we have carried out in my last lectures this is very important. So, first we write the problem and then we will slowly possible to solve that particular problem so, this is the all about the HQ curve.

(Refer Slide Time: 06:05)



Now, if I go to the next slide and if I write the problem; so, problem is like this, find the maximum speed of a single acting reciprocating pump to avoid separation to avoid separation which occurs at 3 meter of water, which occurs at 3 meter of water this is absolute. The pump has a single of diameter the pump has a cylinder has a cylinder of diameter 10 centimeter and a stroke length of 20 centimeter a stroke length of 20 centimeter.

The pump draws water from a sump, the pump draws water from a sump and delivers to a tank and delivers to a tank the water level in the sump is it is written, the water level in the sump is 3.5 is 3.5 meter below the pump axis, below the pump axis. And in the tank the water level and in the tank and in the tank the water level is 13 meter of the pump axis a tank the water level the water level is 13 meter above the pump axis.

The diameter on length of suction pipe it is given that the diameter and length of suction pipe. The diameter and length of suction pipe are 4 centimeter and 5 meter while of delivery pipe, while of delivery pipe delivery pipe the diameter and length are the diameter and length are 3-centimeter 20 meter respectively 3centimeter and 20 meter respectively. Take atmosphere pressure head take atmospheric pressure head is equal to 10.3 meter of water.

So now, we have to solve the problem, we have to solve the problem. So, if I to solve the problem you need to draw the indicator diagram probably, we have discussed about indicator diagram the ideal one, then modified the inertial inertia pressure and then the frictional effect. So, if you try to recall the you know indicator diagram then indicator diagram looks like this that so, this is the solution rather we solve the problem in the next slide, or we can start here also that.

If we draw the indicator diagram this is an the pressure absolute pressure this is also the you know volume then, indicator diagram is like this, we have we have this is the atmospheric pressure so, this is H atmospheric then, we have the ideal one and then we have modified with inertial pressure and then we have frictional effect. So, this is h_s suction and this is only to take the effect of and this is h_{fs} so, this is h fs and this is has similarly, this one so, this will be the h_{fd} and this will be had; so, we are talking we are calling it.

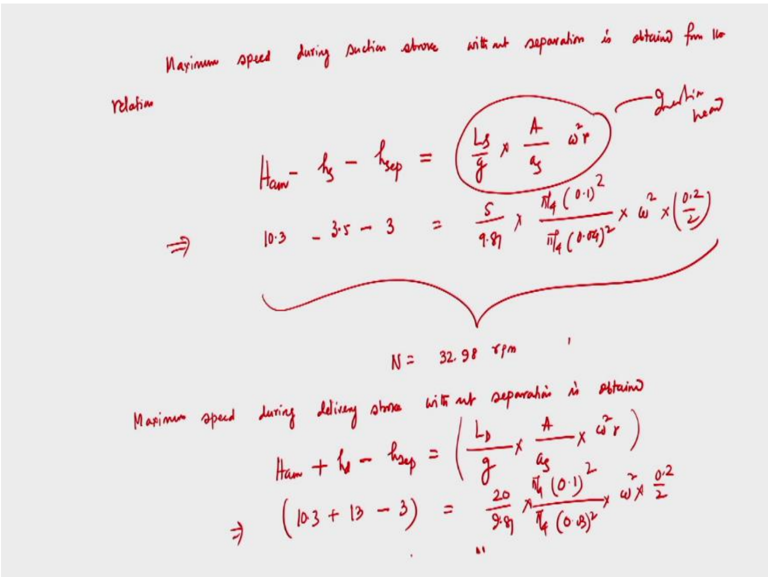
Now this is the indicated diagram modified with different effect like inertial effect and effect due to friction that in the suction and delivery line. Now what is inertial pressure? So inertia pressure that is what curve we have solve Pi = $\rho l \frac{dv}{dt}$ that is what we have written.

Pi = $\rho L \frac{dv}{dt}$ = Pi = $\rho L \frac{A}{a} r\, \omega^2\, cos\omega t$

hi = $\frac{Pi}{\rho g} = \frac{L}{g}\frac{A}{a} r\, \omega^2\, cos\omega t \quad = \pm \frac{L}{g}\frac{A}{a} r\, \omega^2$

So, so that is why you have taken 0 degree to 180 degree and then again 180 degree to 0 degree so, that is why you have taken that is plus minus omega t. So, we have obtain this is the inertial pressure hi. Now so, here I can write that maximum speed we have to calculate the maximum speed of a reciprocating pump to avoid separation. The maximum speed during suction stroke, suction stroke without separation is obtained from the relation.

(Refer Slide Time: 15:57)



Now maximum speed maximum speed during suction stroke during suction stroke without separation, without separation is obtained from the relation

$H_{atm} - h_s - h_{sep} = \frac{L_s}{g}\frac{A}{a_s} r\, \omega^2$

N= 32.98 rpm

So, I know all the values so, because I the stroke length I know. So, omega square r I know and co centimeter so, omega is equal to have to calculate if I try to calculate so, ha t m I know h s is static height that is 1.5 meter and separation that is 3 meter. So, if I calculate using this from there I can calculate omega and speed should be 32.98 rpm so; this is another case.

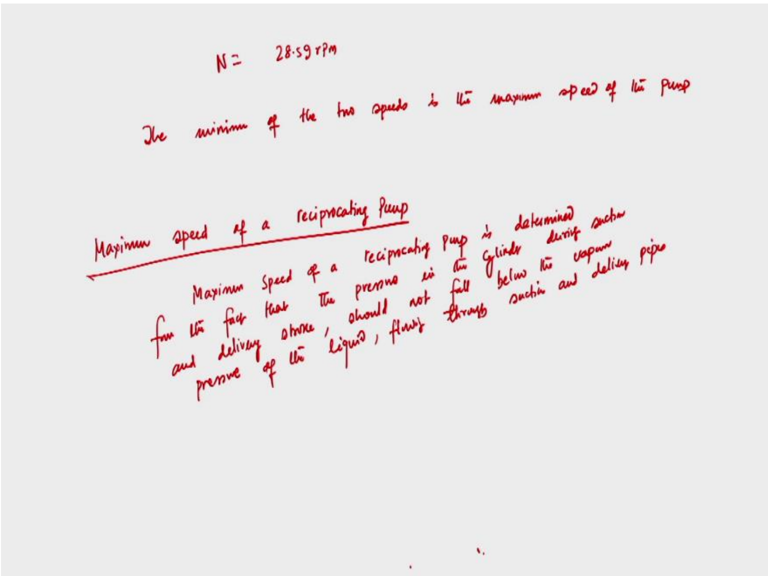
So, this is the maximum speed during suction stroke without separation is obtained from the lessons similarly, you can calculate maximum speed, maximum speed during you know delivery stroke, delivery stroke without separation, without separation is obtain how? Because, atmospheric pressure plus or having you know static height of the delivery tank minus h separation that is of course, that is there is equal to ld length of the delivery pipe divide by g into A divided by as into omega square into r.

$$H_{atm} + h_d - h_{sep} = \frac{L_d}{g} \frac{A}{a_s} r \, \omega^2$$

N = 28.59 rpm

So, you know that hs and hd we know from the schematic that have drawn hs is static height and then had is the effect of inertial head due to inertial pressure and then frictional head. So, now, if I calculate from this equation, we will obtain the value of N the value of N value of; so, I will write in next slide.

(Refer Slide Time: 20:25)



So, value of N will be that you know 28.59 rpm. So, maximum speed during delivery stroke without separation is obtained is the 28.59 operation. So now, the question is find the maximum speed of a single act reciprocating pump about separation which occurs? So, the minimum of these two speeds is the maximum speed of the pump, now question is the minimum of the two speeds is the maximum speed of the pump, two avoid separation and so, that it is given.

So, that is what is the minimum which occurs at the which occurs at the during the delivery stroke. So, this is the maximum speed of the pump to avoid separation. So, maximum now, I am writing that maximum speed of a reciprocating pump maximum speed of a reciprocating pump. So, maximum this is very important, maximum speed of a reciprocating pump is determined from the fact that I am writing this from the fact that the pressure in the cylinder during suction and delivery during suction and delivery stroke should not fall below the vapor pressures, below the vapor pressure of the liquid. This is very important, flowing through suction and delivery pipe, suction and delivery pipes so right.

So, this is important; so, maximum speed of reciprocating pump is determined by the fact that the pressure in the cylinder during suction delivery stroke should not fall the vapor pressure of the liquid flowing through the function and delivery pipes. And how and that is why we have calculated the maximum speed during which during delivery stroke without separation because, separation occurs 3 meter water column.

So, I know the atmospheric pressure head and this is the static height, this is the separation and this is very important $\frac{L}{g} \frac{A}{a} r \omega^2$ this is essentially the inertial pressure, I mean you know inertia head rather I can say this is the inertia head. So, this quantity is the inertia head so, this is inertia head inertia head.

So, if I calculate it and obtained the maximum speed in the suction stroke is 32.98 rpm and maximum during delivery stroke is again coming 28.59 rpm. The minimum these two speeds is the maximum speed of the pump that can be used to operate without having separation of the suction side and that is why you have define that what is the maximum speed of reciprocating pump? Maximum speed of reciprocating pump is determined by the fact that the pressure in the cylinder during suction delivery stroke should not fall the vapor pressure of the liquid following through the suction and delivery pipes.

So, this is one numerical problem that we have solve for this particular PD pump and we have drive that how we can obtain this each h sf right. So, and if we go back to my previous slide, here we have written this is inertia head, this is inertia head and this is omega t because, that this is very important at the crank rotates from 0 degree to 180.

So, when it starts may be suction stroke and it ends, so and again from 180 to 0 degree. So, cos 0 that is at the beginning of the suction stroke it is cos 0 so, that is this one so, inertia head. Similarly, at the beginning of the delivery stroke it is again I mean coming to $\frac{L}{g}\,\frac{A}{a}\,r\,\omega^2$.

So, considering this we have calculated that the minimum of these two speeds is 28.59 rpm and this is the speed at which pump can be operated without having separation. And we have defined the maximum speed of reciprocating pump, and this is very important to move and for that we have to calculate maximum speed during both the strokes I mean suction strokes and delivery stroke.

So with this, I will stop here and I will continue in next lecture.

Thank you.