Principle of Hydraulic Machines and System Design
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Lecture – 15
Pumps Operation: Series and Parallel, Problems – II

So, today we will solve a few problems that we could not solve in my last lectures. So, I will solve one problem for axial flow machines. So, before I go to solve the problems on axial flow machines I will briefly discuss about a few important features whenever fluid is inclined axial flow machines.

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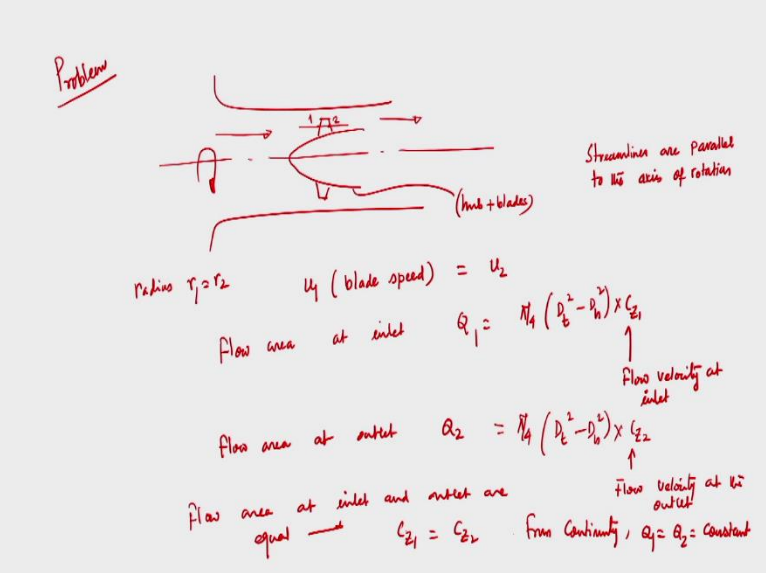

So, I am writing problem it is very important on axial flow machines. So, if I draw the schematic of axial flow machines again. So, this is the hub plus blades that is impeller of an axial flow machines, fluid is flowing in the axial direction and machine is rotating in this direction.

And if I take a streamline; so this is 2 and this point is 1; so 1 and 2. So, you know here stream lines are parallel you know to the axis of rotation, to the axis of rotation. So, here streamlines are parallel axis rotation. So, before I go to solve the problem here, I will discuss that now radius r1 = r2. So, you know half and tips; So, radius r1 = r2 therefore, the blade speed u1 blade speed at the inlet will be equal to blade speed u2 blade speed outlet since you know RPM is same.

Flow area at inlet $Q_1 = \frac{\pi}{4}\left(D_t{}^2 - D_h{}^2\right) C_{z1}$

Flow area at outlet $= \frac{\pi}{4}\left(D_t{}^2 - D_h{}^2\right) C_{z2}$

So, now flow area at the inlet; flow area at inlet and outlet are equal; that means, flow area at inlet and outlet are equal; that means, it will give Cz1=Cz2 So, why? Because flow area at the inlet and outlet are equal this will give Cz1 = Cz2 this is from the continuity equation.

Because from continuity Q1 = Q2 is equal to constant right. So, from continuity Q1 = Q2 = K .

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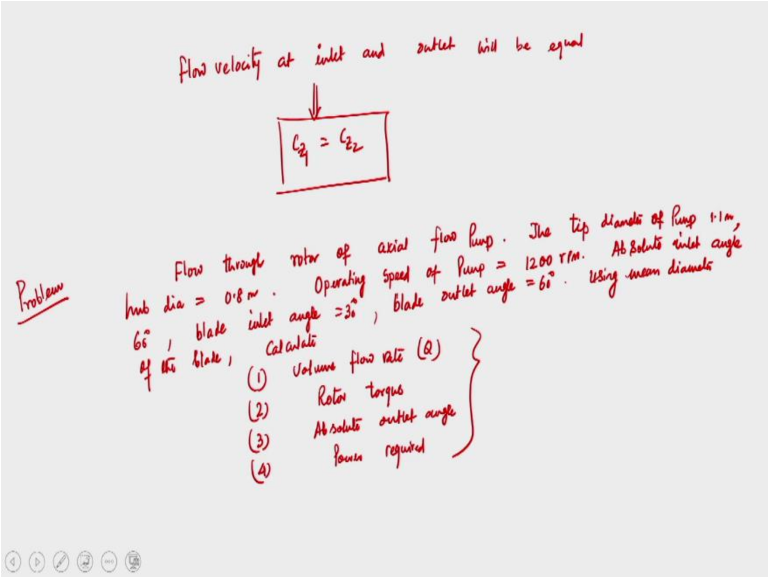

So; that means, if I go to the next slides; so, the flow velocity that means flow velocity at inlet and outlet will be equal; will be equal that is in implying Cz1 = Cz2. So, this is the condition we get from this you know analysis.

That means, if we talk about flow through axial flow machines then since the flow area at inlet and outlet are constant and from the continuity Q1 = Q2. So, it will imply that the flow velocity at the inlet and outlet has to be equal that is Cz1 = Cz2. So, this is the condition rather this is the conclusion what we get from this analysis this will be important while you are solving a problem for the axial flow machines.

Now, we will discuss one problem one axial flow machines and that is very important. So, will discuss one problem I will write the problem; so, flow through rotor, flow through rotor of axial flow fan right. The tip diameter tip diameter of fan is 1.1 meter; half diameter is equal to 0.8 meter.

It is given operating speed sorry it will be axial flow pump; it is axial flow pump at tip diameter of the pump is 1.1-meter half diameter is given operating speed of the pump is equal to 1200 rpm. Absolute inlet angle is given 60-degree, blade inlet angle is equal to given 30-degree, blade outlet angle is equal to given 60 degree.

Use mean diameter of the blade; use mean diameter of the blade rather using mean diameter of the blade; we have to calculate one volume flow rate; volume flow rate Q, number 2 rotor torque, number 3 absolute outlet angle, number 4 power required. So, these 4 quantities we have to calculate based on the data given. So, we need to solve the problem; so, we will solve the problem, now we will solve that solution.

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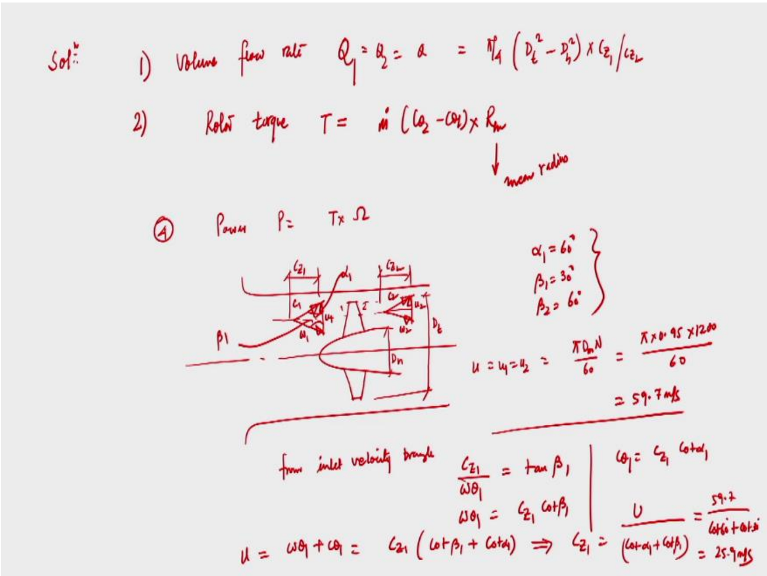

So, volume flow rate volume flow rate Q1 = Q2 = Q whatever it is will be $\frac{\pi}{4}\left(D_t^{2} - D_h^{2}\right) C_{z2}$ whatever we can calculate.

Rotor torque T = m $(C_{\theta 2} - C_{\theta 1})$ Rm

So, R m is the mean radius because bit is given that we have to consider mean radius. So, this will be the rotor torque and finally, if we calculate power then power P will be torque into omega. So, that the answer of 4 that will get Newton meter per second what whatever will that that will obtain that is the power.

Now, we have to solve the problem by drawing the velocity angles. So, now, am drawing the velocity angles of inlets and outlets. So, if it is an axial flow machines or axial flow pump.

So, we have obtained, and this is the half diameter D h and tip diameter will be like this. So, this is the tip diameter Dt; so, you have obtained Dt and Dh, but what is given? We have given flow angle absolute angle absolute flow angle α_1 = 60 degree is given, β_1 = 30-degree, $\beta_2 = 60$ degree.

U1=U2 = $\frac{\pi\ D_m N}{60} = \frac{\pi * 0.95 * 1200}{60} = 59.7$

So, to obtain flow rate we know Dt we know Dh only thing we need to know either Cz1 or Cz2. So, if take the inlet velocity angle; so which one is the alpha 1 is the 60 degree. So, this angle is 60 degree; so, from inlet velocity triangle from inlet velocity triangle we obtain Cz 1. So, this is the Cz1 and this is this is Cz2.

$$\frac{C_{z1}}{W_{\theta 1}} = \tan\beta_1$$

$$W_{\theta 1} = Cz1\ \cot\beta_1$$

$$C_{\theta 1} = Cz1\ \cot\alpha_1$$

U = $W_{\theta 1} +\ C_{\theta 1}$ = $(Cz1\ \cot\beta_1 + \cot\alpha_1)$ Cz1

So, from here we can calculate c z 1 is equal to u divide by cot alpha 1 plus cot beta 1 and it will give a value of because u = 59.7 and if I put the value of cot alpha 1 and cot beta 1 cot 60 degree plus cot 30 degree will obtain the value of 25.9 meter per second. So, we will obtain at flow velocity at the inlet will is 25.9 meter per second, knowing the value of this continuity we can go to calculate Q; Q 1.

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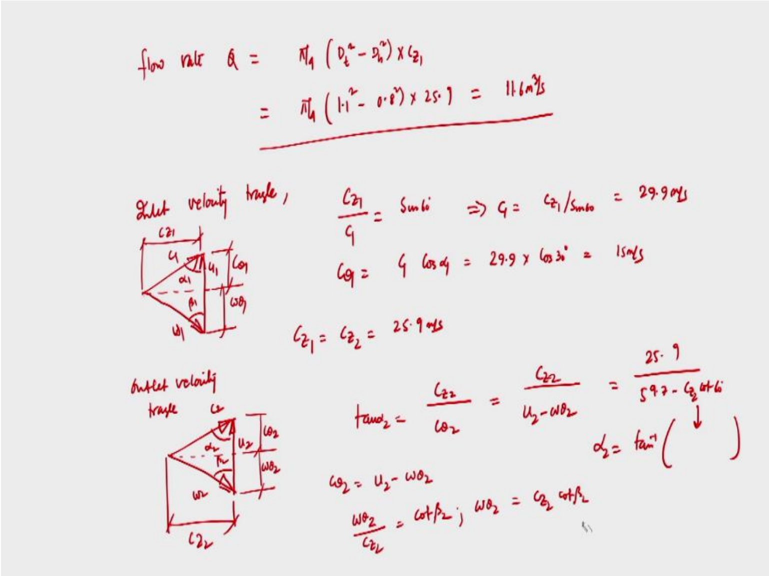

Q= $\frac{\pi}{4}\left({D_t}^2 - {D_h}^2\right) C_{z2} = \frac{\pi}{4}\,(1.1^2 - 0.8^2) * 25.9 = 11.6\, m/s$

So, this is the answer for the flow rate we will obtain now we need to calculate another a few quantities that is a torque. To calculate torque what we need to know you know we need to know the value of $C_{\theta 2}$ and $C_{\theta 1}$ that is the very important.

$\frac{C_{z1}}{C1} = sin60$

C1 = $\frac{C_{z1}}{sin60} = 29.9\, m/s$

$C_{\theta 1} = C1\, cos\alpha 1 = 15\, m/s$

Cz1 = Cz2 = 25.9 m/s

$tan\alpha_2 = \frac{C_{z2}}{C_{\theta 2}} = \frac{C_{z2}}{u2 - W_{\theta 2}} = \frac{25.9}{59.7 - Cz2\, \cot\beta_2}$

$\{\frac{C_{\theta 2}}{Cz2} = \cot\alpha 2\}$

$C_{\theta 2 = 44.6}$

T = m *$(C_{\theta 2} - C_{\theta 1})$ *Rm = 201Nm

Power P = T. ω = 25.3 kW

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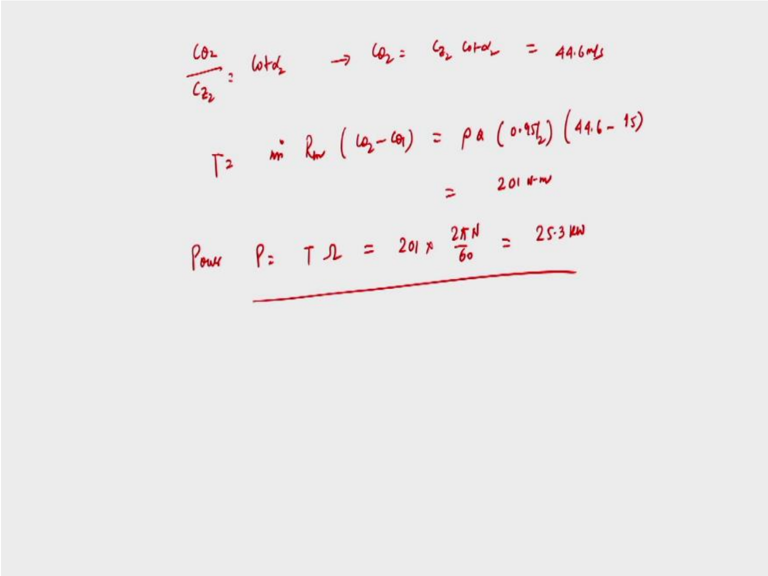

So, essentially what we have to calculate? For the key is for axial flow machine flow area at the inlet and outlet are equal which will give that flow velocity at the inlet and outlet are equal. And from the given data we have to calculate different components of you know velocity right component of axial velocity in the tangential direction at the inlet and outlet, component of electricity at the tangential direction at inlet and outlet; from there we can calculate all other quantities and we have to solve the problem.

With this, I stop here, and we will continue in the next lecture.

Thank you.