Steam Power Engineering

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Lecture - 29
Examples on Turbine 2

We will start the next example. It states that following particulars refer to a two-stage velocity compounded impulse wheel means turbine. Steam velocity at nozzle exit is 600 m/s, nozzle angle is 16; mean blade velocity is 120 m/s.

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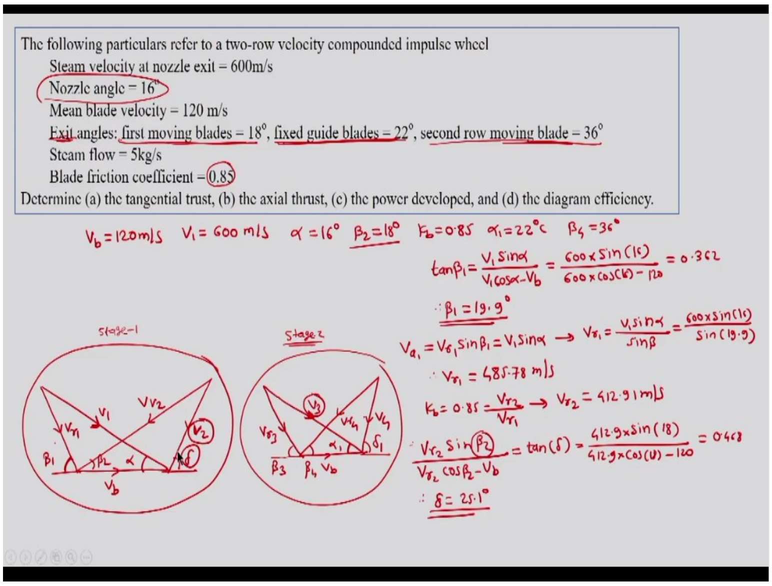

Exit angles are given that is for first row of moving blades, it is given as 18 degree, fixed guide blades it is given as 22 for the exit and second row of moving blades also as exit as 36 degree, steam flow is given as 5 kg per second, blade friction factor is 0.85. Here, we have to remember that we are working with two-stage velocity compounded, so the fixed blades are acting as nozzle.

So, this 0.85 should also act for the fixed blades. What is happening in case of moving blades, we are having relative velocity which will be felt by the moving blades at the inlet. So, due to the friction factor, we reduce the velocity which is relative at the outlet. Similarly, in case of fixed blade, we have to reduce the absolute velocity at the outlet from the reference inlet. So, determine tangential thrust, axial thrust, power developed and diagram efficiency.

First of all, we should draw the velocity triangle and denote whatever it is given to us. so we will refer this as α and this is β_1 since this is V_1, this is V_{r1}, this is V_2, this is V_{r2}. So, this is β_2, this is δ and then we have to draw second velocity triangle, so V_b will be same. So, this is V_b and this is V_3, this is V_{r3} so this is α_1, now this is β_3, this is β_4, this is the angle at the outlet, we will say it as δ_1.

This is V_{r4} and this is V_4 and knowing this we can work out with the example since V_b is given as 120 m/s, V_1 is given as 600 m/s, α is given as 16 degree since it is told that the nozzle angle is 16, so α is given as 16 degree, β_2 which is the exit angle for the first row moving blades is given 18 degree. Then, friction factor K_b is 0.85 and then we are told that α_1 is 22 degree since exit angle for the first guide blades.

So, this is α_1 and then second moving blades so it is given as beta 4 as 36 degree. Knowing this, we should proceed with this example, we can first find out $\tan\beta_1 = \frac{V_1 \sin\alpha}{V_1 \cos\alpha} - V_b$. So, we will have V_1 is $\frac{600 \sin\alpha \sin(16)}{600\cos(16) - Vb}\, is\, 120$ and this gives us 0.362 so we can get $\beta_1 = 19.9\, degree$.

So, we found out β_1, so we can find out from here V_{r1} since $V_{r1}\sin(\beta_1) = V_1 \sin(\alpha)$. So, $V_{r1} = V_1$ basically this is V_{a1}. $\frac{V_1 \sin(\alpha)}{\sin(\beta)}\, so\, it\, is\, \frac{600\sin(16)}{\sin(19.9)}$, so $V_{r1} = 485.78\, m/sec$. Now, we are told that friction factor $K_b = 0.5$,we know it is $\frac{V_{r2}}{V_{r1}}$ so $V_{r2} = 412.91\, m/sec$.

So, we can find out the outlet absolute velocity angle as $\frac{V_{r2}\sin(\beta_2)}{V_{r2}\cos(\beta_2)} - V_b = \tan(\delta)$. So, we are finding out this angle δ. Now, we know V_{r2}, we know β_2 so we can make use of this. So, V_{r2} is $412.9\sin(\beta_2)$ is given $\frac{18}{412.9}\cos 18 - 120$. So, we get from here $\tan(\delta) = 0.468$. So, $\delta = 25.1\, degree$.

So, we got absolute velocity angle at the outlet. Now, we are done with the inlet and outlet velocity triangle for stage 1. Now, we will work for stage 2. We know that from stage 1, for stage 1, V_1 was the velocity at the inlet, for stage 2, V_3 is the velocity at the inlet but V_3 is inspired from V_2. So, V_3 and V_2 are the velocities for the fixed blades. So, V_2 is the velocity at the entry to the fixed blade and V_3 is the velocity at the outlet of the fixed blade. So, we have to use the friction factor between them.

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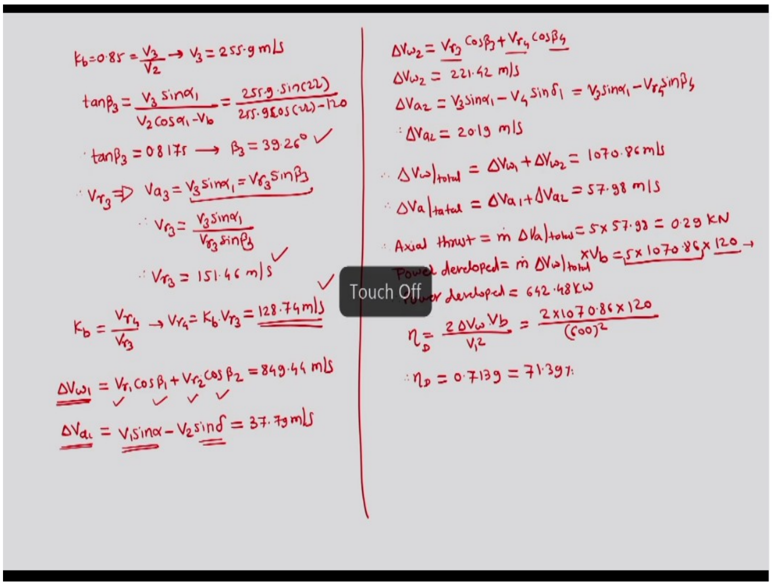

So, friction reduces the velocity so we have $K_b = 0.85$ and then that is equal to $\frac{V_3}{V_2}$ and this gives us $V_3 = 255.9\, m/sec$. Then, we can find out tan (β_3) is ¿ $\frac{V_3 \sin(\alpha_1)}{V_3 \cos(\alpha_1)} - V_b$. $\alpha_1$is given as 22, so $\frac{255.9 \sin(22)}{255.9 \cos(22)} - 120$. So, this gives us$\tan(\beta_3) = 0.8175$ and gives us $\beta_3 = 39.26\, degrees$.

And this is useful to find out V_{r3} which is relative velocity at the inlet for the second stage and that is again we can have found $V_{a3} = V_3 \sin(\alpha ¿¿ 1) = V_{r3} \sin(\beta_3) ¿$. So, we can use this, so $V_{r3} = \frac{V_3 \sin(\alpha_1)}{V_{r3} \sin(\beta_3)}$. So, we have $V_{r3} = 151.46\, m/sec$. Now, we can also find out V_{r4} from the fact that $\frac{V_{r4}}{V_{r3}} = K_b$.

So, we have $V_{r4}=K_b V_{r3}$ so $V_{r4}=128.74\, m/sec$. So, now we found out all the velocities required for all the inlet and outlet velocity triangles for the second stage. Now, we will go back and find out tangential and axial forces. So, for that we will find out change in velocities. So, ΔV_{w1} here 1 means stage 1 is equal to we know it as $\Delta V_{w1}=V_{r1}\cos(\beta_1)+V_{r2}(\beta_2)$.

So, we can write that down and then we can get we know $V_{r1}\cos(\beta_1)$, $V_{r2}\cos(\beta_2)$ and then we can get it as 849.44 m/s. Similarly, for axial thrust change in axial velocity for stage 1 is equal to $V_1\sin(\alpha)-V_2\sin(\delta)$ and so that we have found out $\delta 's$, we have found out alpha is known, V_1 is known, we can find out this and we get it as 37.79 m/s.

We will go for second stage and find out ΔV_{w2} that is $V_{r3}\cos(\beta_3)+V_{r4}\cos(\beta_4)$ and this gives us ΔV_{w2} as $221.42\, m/sec$, V_{r2} is found, V_{r3} is found out, V_{r4} is found out, β_3 is known, β_4 is given. So, from that we found *out* ΔV_{w2}. So, similarly $\Delta V_{a2}=V_3\sin(\alpha_1)-V_4\sin(\delta_1)$ but this is also equal to $\Delta V_{a2}=V_3\sin(\alpha_1)-V_{r4}\sin(\beta_4)$ since β_4 is given to us.

So, from that $\Delta V_{a2}=20.19\, m/sec$. So, $\Delta V_w \vee ¿_{total}=\Delta V_{w1}+\Delta V_{w2} ¿$ and we get it as 1070.86 m/s and$\Delta V_a \vee ¿_{total}=\Delta V_{a1}+\Delta V_{a2} ¿$ and then that is 57.98 m/s. So, we can find out axial thrust is equal to $\dot{m}\,\Delta V_a \vee ¿_{total} ¿$ and that is equal to $5\times 57.98$and then this is 0.29, we will get this answer in Newton.

We are expressing it into kilonewton as 0.29 kilonewton. Similarly, we can find out power developed and this is $\dot{m}\,\Delta V_w \vee ¿_{total} V_b . ¿$ So, this is $5\times 1070.86\times 120$. So, we have power developed. Here, this amount is tangential thrust into 120 is power developed, so we will get power developed this will come in Watt so we will get in kilowatt as 642.48 kW.

So, we know diagram efficiency is equal to $\eta_D=\dfrac{2\Delta V_w V_b}{V_1^2}$. So, we have $\dfrac{2\times 1070.86\times 120}{600^2}$.

So, diagram efficiency is $\eta_D=0.7139 \vee 71.39\%$. So, this is the example for two-stage velocity compounded example and here we understood one new point that if friction factor is given, then we have to use it not only for the moving blades but also for the fixed blades such that we should find out the absolute velocity which is approaching the moving blades of second stage.

And rest of the things we should continue calculating as what we do for single stage impulse and then we have to add the tangential thrusts, we have to add the axial thrust to get the total tangential thrust and total axial thrust and then we can found out total power developed or the diagram efficiency. Thank you.