Steam and Gas Power Systems
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Module No # 06
Lecture No # 30
Problem Solving (Steam Turbine)

Hello I welcome you all in this course on steam and gas power systems today we will solve the problems on steam turbines and that will conclude on how discussions in steam turbine

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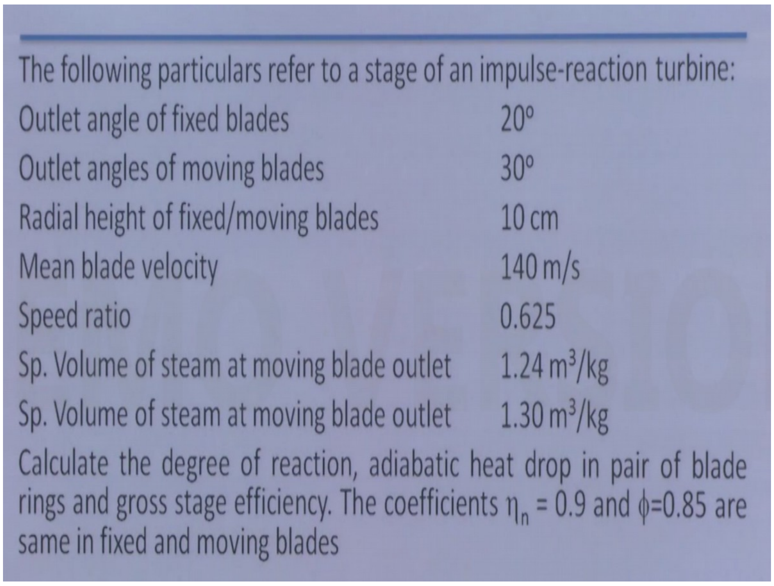

The first problem is the following particular refer to a stage of an impulse reaction turbine this is about the impulse reaction turbine outlet angle of fixed blades is 20 degree.

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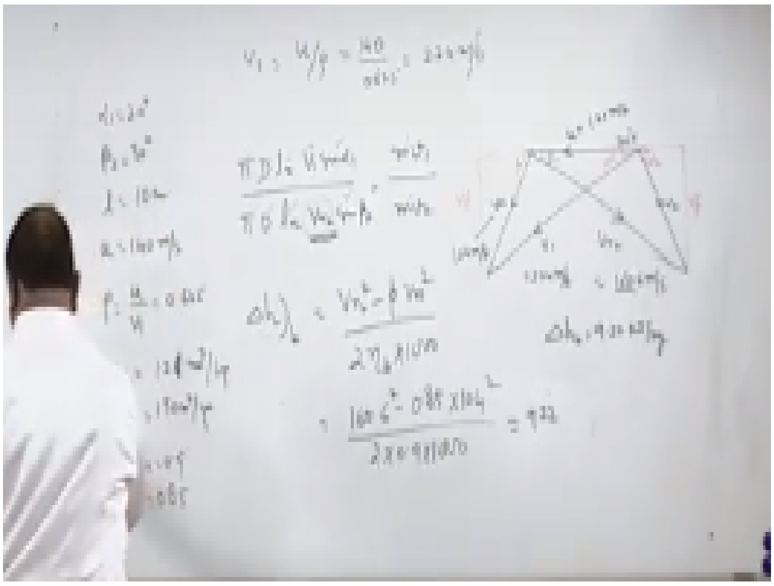

So simultaneously we will start drawing the velocity diagram also this is V1 this is VR1 this is peripheral velocity U this is VR 2 V2 and angles this is beta 2 this is beta 1 blade outlet, angle blade inlet angle, nozzle inlet angle and nozzle outlet angle right and so outlet angle of fixed blades is 20 degree. So outlet angle of fixed blades means fixed blades of previous stage so that becomes alpha 1 nozzle inlet angle so alpha 1 is 20 degree then outlet angle of moving blades.

Now the outlet angle of moving blades is beta 2 beta 1 is inlet blade angle beta 2 is 30 degree radial height of fixed and moving blades. So radial height of the blade L is 10 centimeters or . 1 meter mean blade velocity U is 140 meters per second speed ratio is U row U by V1 = 0.625. So specific volume at moving blade inlet is so VS1 is 1.24 sorry 1.24metre cube per kg and specific volume of steam at moving blade outlet.

So VS 2 is 1.30 metre cube per kg then calculate the degree of reaction it is not parson turbine right so we have to calculate the degree of reaction adiabatic heat drop in pair of blades total heat drop the heat drop in the nozzle and heat drop in the blade sum of that gross stage efficiency, coefficient efficiency of the nozzle is .9 or 90% and carry over coefficient is 0.8 and they are same in fiction moving blade ok.

So first of all since velocity is given so we can find the peripheral velocity is given we can find the inlet velocity inlet velocity is that is going to be 140 by 0.625224 metres per second. So this V1 = 224 metres per second. So steam is coming at this alpha 20 degree centigrade it is 20 degree centigrade and U is also with us that is 140 metres per second .

So now we can easily draw the inlet angle because this base is known this alpha is angle is known this vector is known 224 metres per second and we can draw the triangle and analytically also we can find the value of beta1 or VR1 or VF1 whatever value is required now after this we will do the we will use the continuity question continuity question say that area pie D LN V1 sign alpha 1.

What does it mean? It means that velocity of flow V 1 is (()) (05:06) is velocity of flow multiplied by area pie D LN blade passage area of blade passage so this is the height of the blade and this is we have taken periphery entire periphery the error number of blades. So multiplied by the height of the blade this will give the area velocity of flow will give MV 1 this is a conceptual continuity equation which is used in different mechanics.

Now again pie D Ln VR 2 sign beta 2 that is VR 2 sign beta 2 will give us the MY 2 now pie D Ln again this is the area multiplied by the velocity of flow at the outlet. So velocity of flow flow velocity multiplied by the passage area flow velocity multiplied by the passage area right now if now here why you we have taken this we have taken this if we take the ratio of this we have value of V1 and V2 as well.

Right this will be cancelled out if you take the ratio of these 2 now if we take the ratio the pie will be cancelled out D will be cancelled out Ln will be cancelled out M will be cancelled out V 1 and V2 are already with us right. So we need not calculate them V1 is with us V sign alpha is with us sign beta 2 because VF can also be V2 sign alpha 2 or VR 1 sign beta .

We do not have these values we have taken already those vectors for which we have the values but we do not have the value of VR 2 this value is not with us right. So in order to find this so we have to find the value of VR 2 and this is all the other values are known by putting these values we are getting the value of VR 2 as 160.6 metres per second. Now we have the value of VR 2 also with us ok.

Now we have to calculate isentropic heat drop in blades for calculating isentropic heat drops in the blades .We need VR 2 square 1 five VR 1 square divided by 2 efficiency of the blades into 1000 this is the formula efficiencies of the blades is also efficiency of the nozzles we can take 0.9 VR 2 is here 160 but you do not have the value of VR 1 but since we have the other values in this triangle.

We can always find the value of VR1 square = V1 square + U square 1 2 U V 1 cos alpha 1 V 1 is 224 square + 140 square 1, 2 into 140 into 224 cos 20 and this finally gives the value of VR1 as 104 metres per second from here we will get the VR1 square then will take under root of VR1 we are getting 104 metres per second as VR1.

Once we have the value of VR1 with us now 5 is also given 50.85e we can find VR2 is 1 60.6 square 10.75 into 104 square divided by 2 into 0.9 into 1000 sorry this is 85 right and this will give the enthalpy drop in the blades as 9.22. So enthalpy drop in the blade is9.22 kilo joules per kg.

Right now we have to calculate the enthalpy drop min type nozzles as well and in order to calculate the enthalpy drop in the nozzles we need the value of absolute velocity 2 absolute velocity what is known but we need to have the absolute velocity 2 V2.

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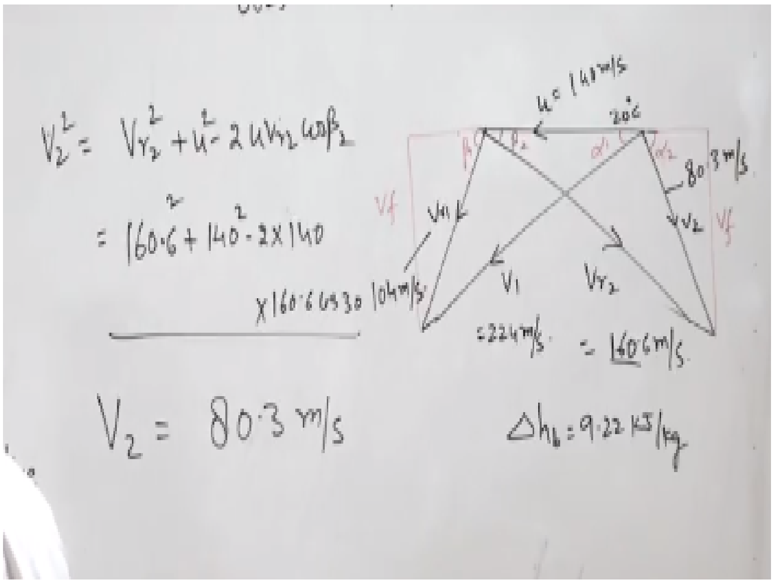

And V2 square again we will find V2 square = VR2 square + U square 1 2 U VR2 cos beta 2.

Geometrically also it can be d1 but if you do it numerically we will be getting better accurate value now VR2 is 160.6 + square + 140 square 1 2 into 140 into 160.6 cos 30 right and this will give the final value of V2 as 80.3 metres per second. So V2 is 80.3 metres per second right and now if i want to find or if i wish to find the enthalpy drop in the nozzles because that will give the total stage enthalpy drop.

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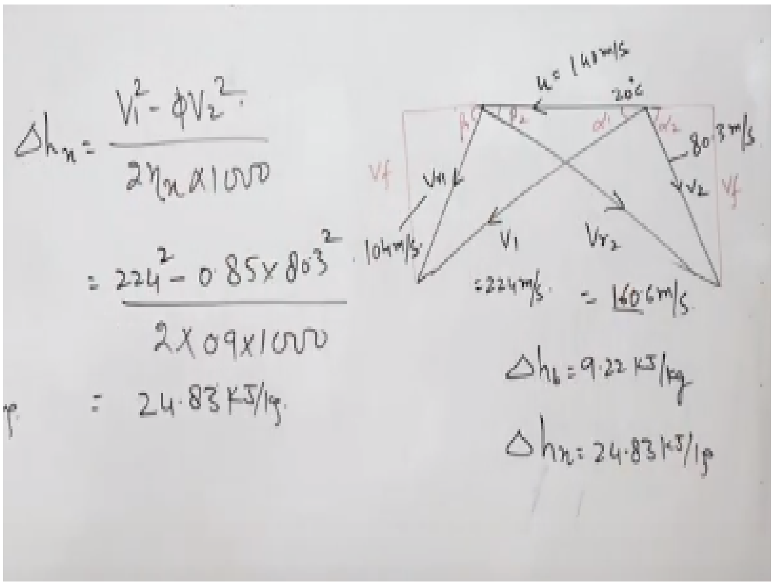

Enthalpy drop in blades enthalpy drop in the nozzle so enthalpy drop in the nozzles is going to be = V1 square 1, 5 V2 square by 2 nozzle efficiency into 1000 in order to convert rate into the kilo joules and that is V1 is 224 meter per second 10.85 multiplied by 80.3 square divided by 2 efficiency of the nozzle is .9 multiplied by 1000 and this will give the enthalpy drop in the nozzle is 24.83 kilo joules per kg.

It means delta HN = 24.83 kilo joules per kg now in order to find the degree of reaction now we have the values of enthalpy drop in nozzles enthalpy drop in blades.

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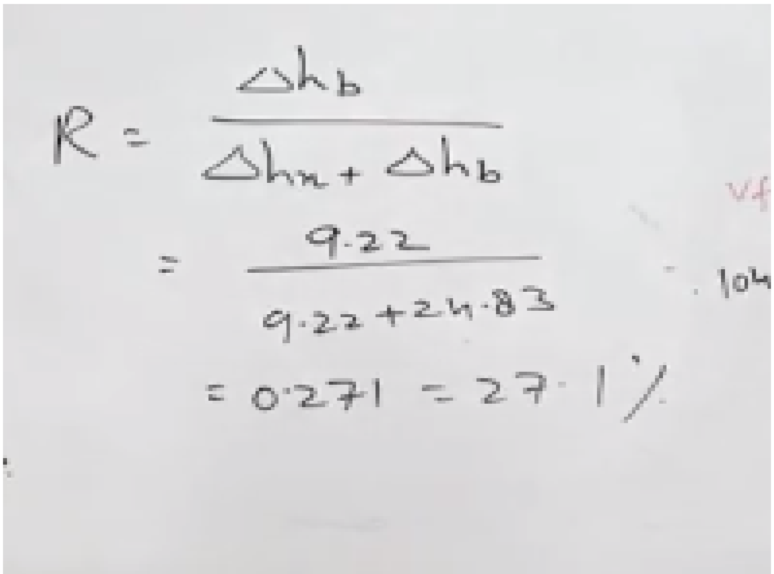

So degree of reaction is delta H blades divided by delta H nozzles + this is isotropic the ideal case and delta Hb. so it is going to be 9.22 divided by 9.22 + 24.83 and this degree of reaction is going to be 0.27 or 27.1%.

This is the degree of reaction of this particular stage now adiabatic heat drop in pair of blade rings gross stage efficiency now we have to find gross stage efficiency in order to find gross stage efficiency we should know the output of the turbine VWU.

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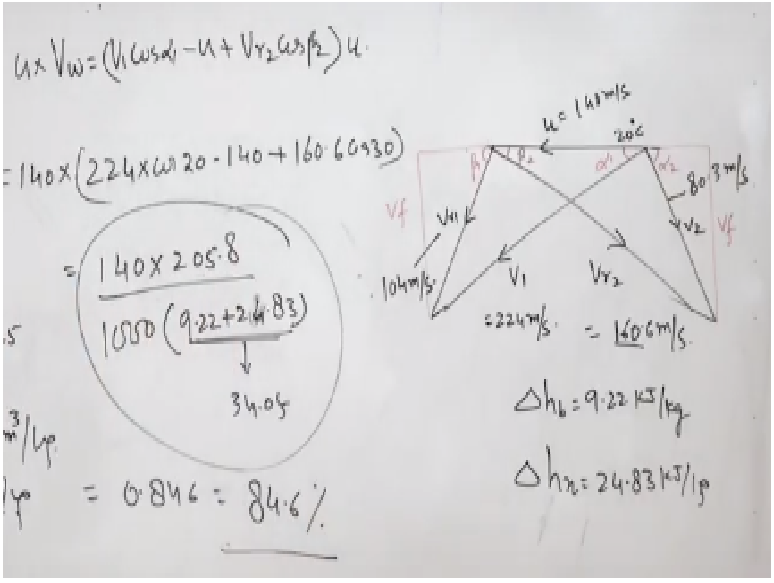

So VWU VW will velocity is going to be equal to we know the value of alpha and sorry alpha 1 blade inlet angle and sorry nozzle inlet angle and blade outlet angle.

So we will take V1 cos alpha 1 1 U + VR2 cos beta 2 and then we will multiply this by U that will give the output multiplied by U right so V 1 is 224 cos 21, 140 + VR 2 160.6 cos 30 this is multiplied by i will write here 140 ok and this will be 140 multiplied by 205.8 divided by enthalpy drop in the stage that is divided by 1000 because it is in enthalpy drop is in kilo joules.

So 9.22 + 24.83 so when these are added it is 34.05 and this ratio is 0.846 or 84.6% right. Similarly, we will try to solve another numerical this is about the passes turbine so in passes turbines we always know that degree of reaction is half point five and in parson turbine

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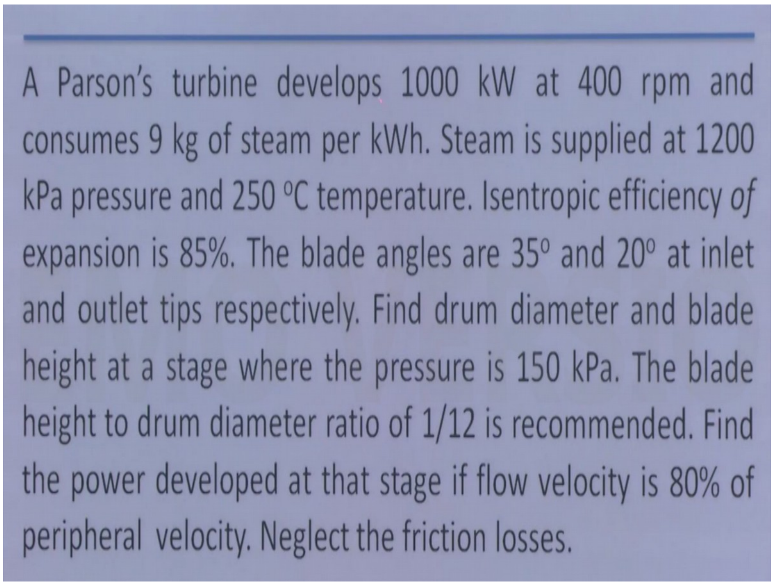

Develops 1000 kilowatt power vat 400 rpm and consumes 9 per kg of steam kilo watt hour. So per unit of power generation or 1 kilo watt power generation it consumes 9 kg of a steam steam is supplied at 100 kilo pascal pressure and 250 degree centigrade temperature. So this is the pressure it is 400 kilo pascal or 12 bar pressure and temperature is 25.

So it appears three at the super heated steam isotropic efficiency of expansion is 85% the blade angles are 35 degree and 20 degree at inlet and outlet tips respectively. So blade inlet and outlet angle are given find drum diameter a diameter of the shaft and blade height at the stage where pressure is 150 kilo Pascal the blade height to drum diameter ratio is 1 is to 12 ratio of 1 is to twelve is recommended .

So ratio of blade height and the drum diameter is 1 is to 12 find the power developed at the stage if flow velocity is 80% of peripheral velocity neglect the friction losses right so here first of all we will draw the

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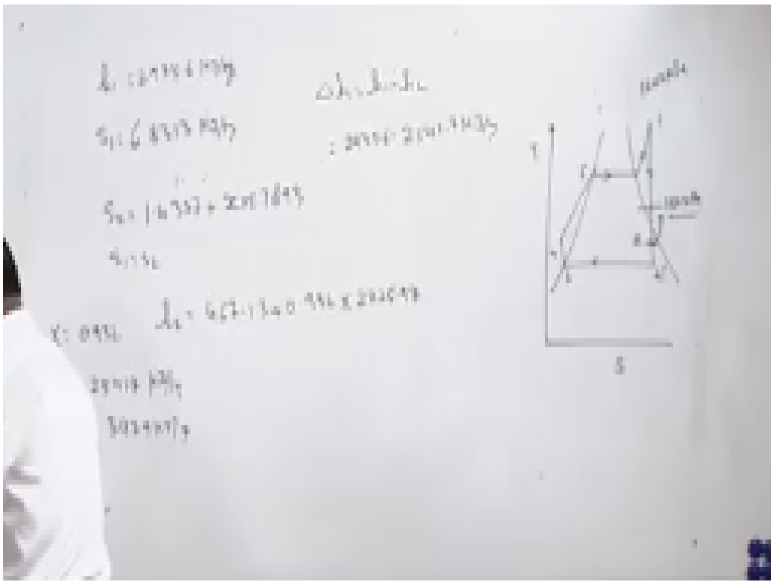

Temperature entropy diagram because it is required here of a right hand triangle because the steam turbines they work on right angled triangle 1, 2, 3, 4, 5. So try to understand this numerical because this steam is entering the turbine at 12 bar so steam entering here is 1200 kilopascal it is it appears to where super heated steam and stage.

We are analysing when the pressure is reduced to 150 kilopascal so the pressure is reduced to 150 kilo Pascal that stage we are analysing so first of all we must know the state of the steam at this stage right.

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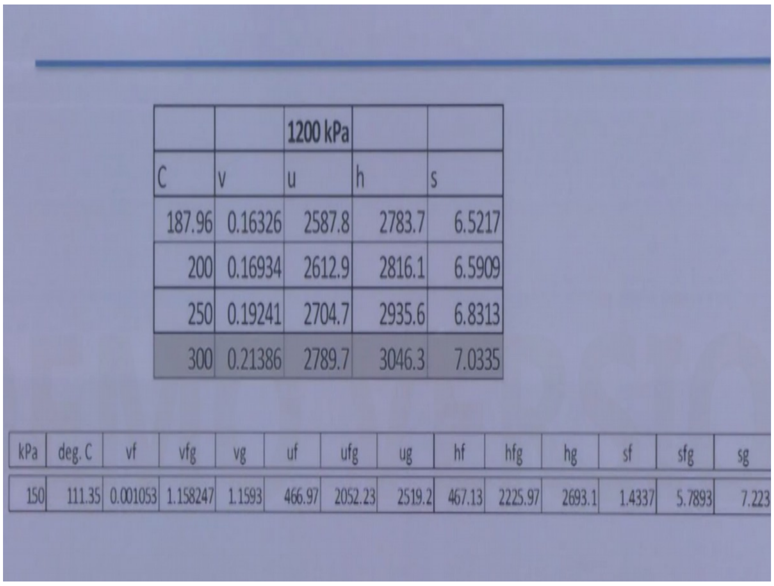

		1200 kPa		
C	v	u	h	s
187.96	0.16326	2587.8	2783.7	6.5217
200	0.16934	2612.9	2816.1	6.5909
250	0.19241	2704.7	2935.6	6.8313
300	0.21386	2789.7	3046.3	7.0335

kPa	deg. C	vf	vfg	vg	uf	ufg	ug	hf	hfg	hg	sf	sfg	sg
150	111.35	0.001053	1.158247	1.1593	466.97	2052.23	2519.2	467.13	2225.97	2693.1	1.4337	5.7893	7.223

So H 1 1200 kilo Pascal saturation temperature is 187.96 so at 250 the enthalpy is 2 935.6 this is the enthalpy of a steam right. S 1 if you remember what we have d1 during the analysis of vapour cycle the entropy of 6.83 kilo joules per kg now it is expended to 150 kilo Pascal.

So 150 kilopascal saturation properties are here and steam is definitely at this pressure because 150 kilopascal is very low pressure.

So steam is definitely somewhere here right so a steam is a mixture of liquid and vapour and entropy here is of saturated vapor is 7.223 it means it is a (()) ((19:51) steam. So entropy is remaining constant and S2 = SF 1.4337 + X SF G that is multiplied by 5.7893 and S1 = S2 and from here we will get the value of X.

The value of X is from here it is coming as 0.932 that is the quality of a steam at this stage when the pressure is 150 kilo Pascal now at this stage we will calculate enthalpy H2 and H2 is again HF is 467.93 + 0.932 multiplied by latent heat 2.97 and this gives the enthalpy at stage 2 or this is not state 2 this is 2 dash.

This is state thus is state 2 right. So enthalpy at state 2 is 2541.7 right and H1, H2 now why we are doing this we are doing this because once we know the H1 H 2 and then delta H = H 1 1 H 2 that is 29335.6 1 H 2 is how much kilo joules per kg 2541.7 kilo joules per kg.

So H 2 1 H 1 is delta H is 393.9 kilo joules per kg ok now specific volume also we can calculate here specific volume V2 = X V2 is quality multiplied by specific volume that is 1.1593 and there is going to be = 1.08 kg meter cube per kg now mass flow rate now if you look at the statement of the problem nine kg of a steam per kilo watt hour.

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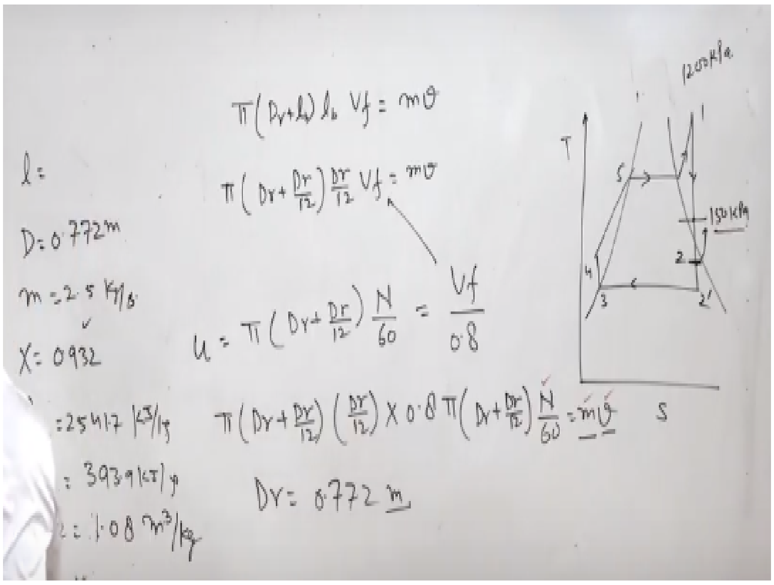

It means mass flow rate is nine kg of a steam multiplied by kilo watt it is 1000 divided by hour and this gives the mass flow rate as 2.5 kg per second right. Now we will do we will use the continuity division again pie DR + height of the blade into height of the blade multiplied by VF = MY same equation we are used in continuity equation .So it is pie DR + DR by 12 DR by 12 VF =MY and U peripheral velocity U =pie DR by DR by 12 M by 60 pie Dr and M is given here.

400 rpm and that is going to be equal to find the power if flow velocity 80% of the peripheral velocity it means this =VF by 0.88% of peripheral velocity is VF this =VF by 8.8 so value of VF we can put here from here right and the equation becomes pie DR + DR by 12 into 0.8 pie DR + DR by 12 N by 60 =MY M.

We are having with us a specific volume is also with us so we have mass specific volume mass is given here specific volume we have already calculated N is with us right and Dr is not with us height of the blade is ratio is given .So we do not require height of the blade only unknown here is Dr right. So we can write and we can solve this and we will get the value of DR as 0.772 simply.

What we have to do? We simply it will come DR cube = something 1 DR will come from here 1 DR is here**.** So DR cube multiplied by some value is product of mass and specific volume and then again we will take the cubic rule and we will find the value of DR so DR is 0.772 meters this is the drum diameters when drum diameter is with us we can always find height of the blades height of the blade is from diameter by 12.

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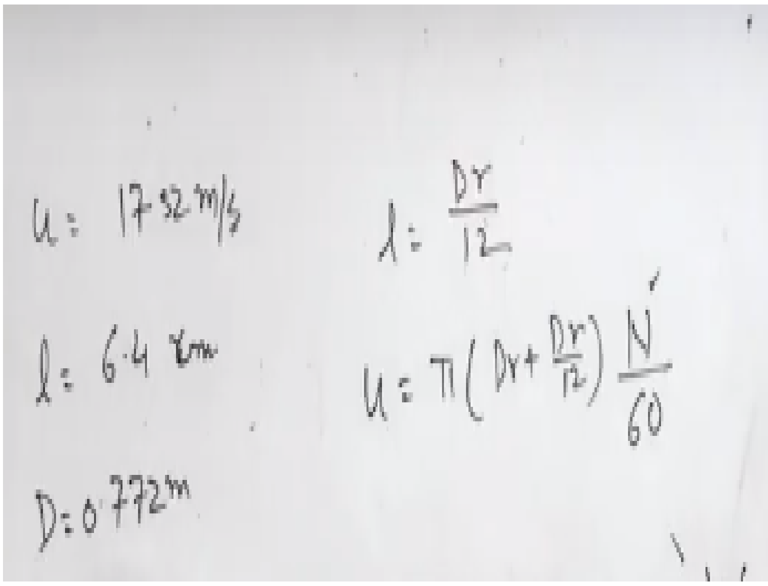

So height of the blade is DR by 12 and once DR is with us L can be calculated it is calculated as 6.4 milli centimetre 6.4 centimetre height of the blades and U now U =pie DR + DR by 12 once we have the DR N by 60 N we are already having so we can calculate the value of U also and that calculated value of U is 17.52 meters per second right.

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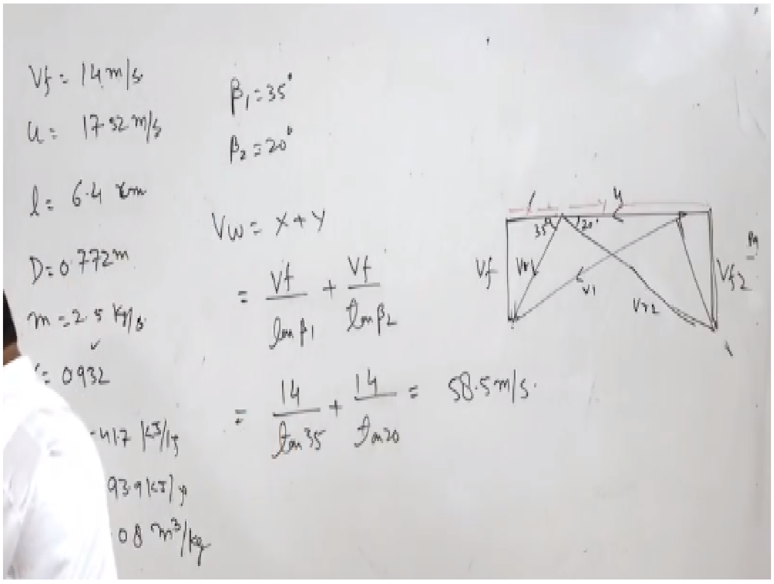

Now velocity of flow once we have the value of U the velocity of flow is 0.8 into 17.52 and this gives the velocity of flow as 14 metres per second this is the velocity of flow and now we have to calculate because we have to calc we have to find the power developed at this stage. So for calculating the power developed we need to have the value of VW will velocity.

So we will draw a triangle this is UV1, VR1, VR2, V2 now here blade angles are known 35 and 20, 35 and 20 we know only beta 1 is beta 1 is 35 degree and beta 2 is 20 degree and we have the value of VF so if we properly draw this diagram actually VF1 = VF2 there is no carry over. So VF1 so these there are =VF1 and this is VF 2 so this is component VF1 and VF2 both are equal right and so now if V if we have to calculate the value of VW.

Vw will be this is VR1 this line + this line this is X and this is Y right and this is the total will comp1nt so VW is X + Y and X = this is VF1. So VF is constant so VF divided by 10 beta 1 + VF divided by 10 beta 2 right = VF we are already having with us 14 by tan 35 + 14 by tan 20 right and this will give the value of VW as 58.5 meters per second.

Now this value of VW will be multiplied by 14 that is peripheral velocity and in order to find the power developed.

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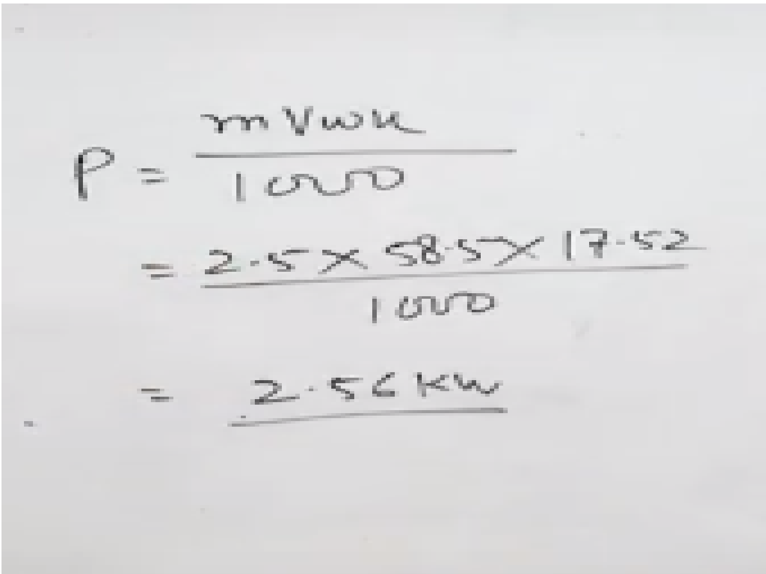

Power developed is MVWU by 1000 that is the power developed on kilo watts mass flow rate. We are having 2.5 kgs per second VW is 58.5 U is 17.52 divided by 1000 and that will give power developed as 2.56 kilo watt in (()) (31:35). Right that is all for today from the next class we will start with the gas turbines thank you very much.