Steam and Gas Power Systems

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Module No # 6
Lecture No # 28
Energy Losses in Steam Turbine

Hello I welcome you all in this course of steam and gas power systems. Today we will discuss about the energy losses in steam turbines because no machine is 100 % efficient. Even in the heat engines all the processes are ideal processes. The efficiency is not 100% right, so is the case of the steam turbine. The steam turbine in addition to the thermodynamic efficiency there are certain losses also.

And the losses takes place in different stages, so we will take up the losses as internal losses. So the external losses and we will carry out one work example on the losses in steam turbine. Regarding the internal losses in the steam turbines, they are dependent upon the state of steam while flowing through the steam turbines

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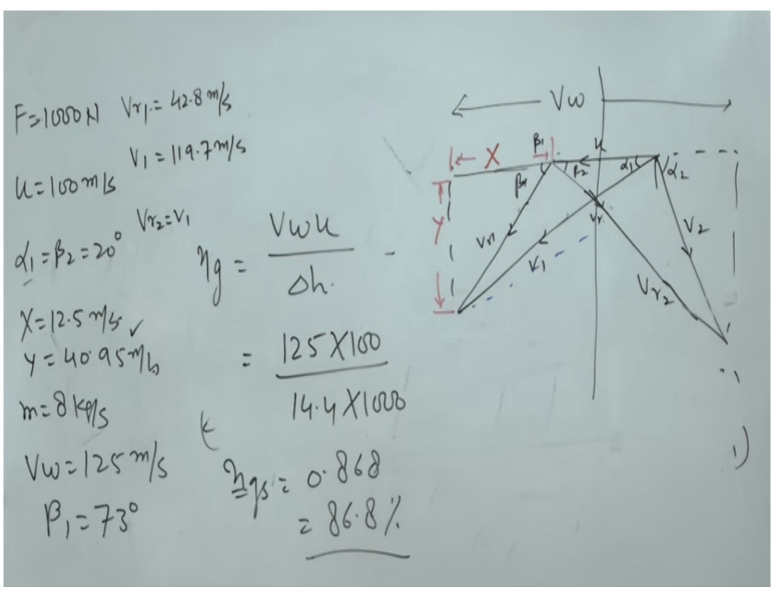

So the state of steam is important while it is flowing through the steam turbine. We will start with the first laws which takes place when steam enters the steam turbine that is regulating wall or steam stop wall or main stop wall it is an integral part of the turbine right. So we must start with regulating wall losses as we know any fluid which passes through any wall in fact passes through a thought link process.

So on a H phi diagram R enthalpy entropy diagram, if I want to show the thought link process it is a constant enthalpy process. This is pressure P1 and this is pressure P2, it is a constant enthalpy process but the pressure reduces and that changes the state of the steam also. This may have been that steam which is entering the turbine is saturated after trundling it becomes superheated steam.

Now regarding the expansion of steam is taking place suppose from state 1 to state 2 expansions in ideal case. When there is no trundling at all but since the trundling is taking place the available energy will be like this and this will be loss of energy during the trundling process. And this pressure loss also because suppose here it is ten bar, now steam may be entering may be 9.8 bar right.

So when steam is entering at nine point eight bar it will be expanded to cost and pressure line. So now we are getting work out of this, earlier we are getting work out of this so definitely output it will be affecting the output of the turbine also. So it is considered as loss and the magnitude this delta P R. This is pressure loss in turbidity wall is 3 to 5 % of B1.

So in a well designed wall it is 3 % and in a poorly designed wall it can go to 5 %, 6 % or 7 %. So range remains between 3 to 5 %. So that is the first energy loss when steam moves into the turbine. Now the second loss is now after entering the turbine.

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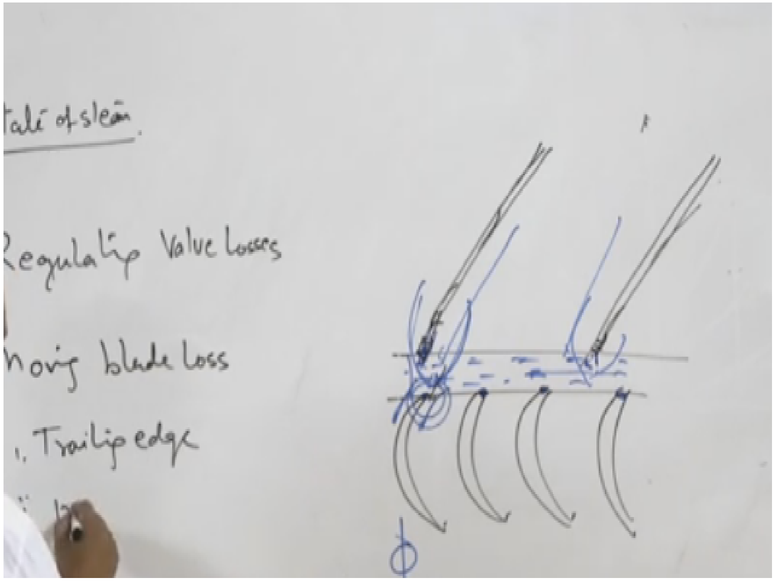

Second is moving blade loss, energy loss also takes place inside the nozzles. We will consider them later on, so now we will focus on moving blade loss. Now in moving blade loss first is let us take a nozzle and through this nozzle there are number of blade passages right. Nozzle has certain wall thickness right and steam is flowing in this direction and this wall does not exist in this alveolar space.

This wall does not exist in alveolar space so there is a mixing of steams here and this mixing cause turbulence wherever turbulence is caused the losses will take place. So here because this is smooth channel, this is smooth passage uniform mixing is there, eddies are formed. Eddies are formed at H of the nozzle and due to these formation of eddies or mixing of two steams some losses takes place right.

In addition to this now the steam is uniformly spread in this alveolar space. This is the space between the nozzle exit and the blade inlet. There is a clearance, so in this clearance when the steam enters due to weight in this position because there is no steam coming from here it is steam is either coming from this side or coming from this side and they are mixing here this causes certain amount of losses.

Next step from this passage steam enters here, now blade H it obstructs the flow of steam right when obstruction is there in any losses are bound to happen. So blade has to be designed in such a manner that these losses are minimum because we cannot make them zero, there have to be some losses. But these losses is by trailing edge of the nozzle or at entry of the blade they are minimized to zero this nozzles also are refracted.

When we saw the numerical in carry over coefficient phi so this phi has always value less than one it is approximately .75, normally it is .75 to .8 and that is due to this reason on. Now this loss is when the steam is entering in the blades it is known as imping loss. So this is trailing edge loss, and second one is imping loss.

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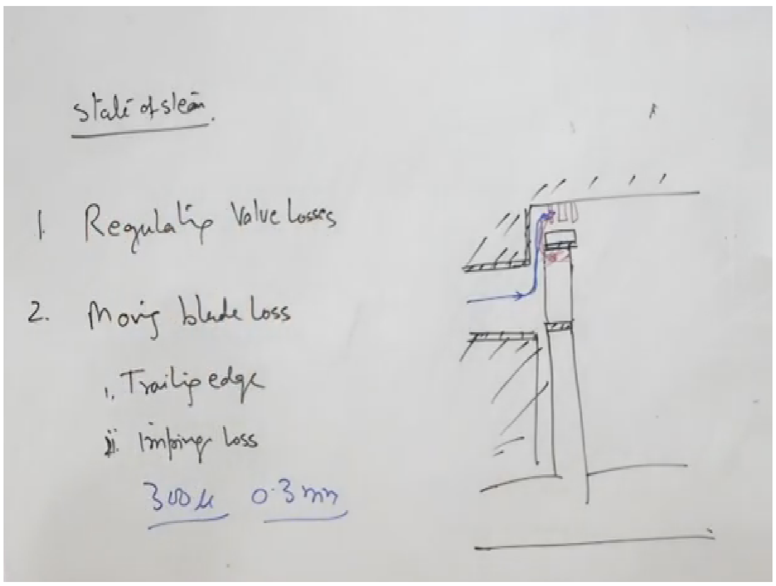

Now in steam turbines the blades are mounted on a shaft right and nozzles are used in a impulse turbine, the nozzles are used for supplying steam to the turbine blades. So this is the nozzle and steam is coming through this nozzle and we will take a turbine blade which is fixed on a rotor this is also fixed on a rotor and steam, and this line will also. Now steam is entering this blades from this direction there has to be some clearance between the end of this blade and the housing.

I mean this clearance has to be there normally this clearance is of the order of 3000 microns or 0.3 millimeters. But there has to be some clearance so this clearance is minimized because what is going to happen is when steam enters the alveolar space it will try to move in this direction and it will flow pass the blade. So this part of the steam will not take any part in power generation it is wastage or leakage loss.

So this flow of steam in this clearance is wastage of energy. Now this has to be prevented, the one way of preventing is say especially in impulse reaction turbine if the degree of reaction is high this steam is separate or another way of doing it is just increase the blade height there is going to be partial admission of steam in this region or weight will be created. Now this weight will suck back the steam.

So steam which was passing over this blade between the clearance, between the housing and the blade will be sucked back in the passage of the blade. So that is how we can but leakage still admitting with the help of these arrangements, also the leakage cannot be completely minimized or reduced but it cannot be completely eliminated. So this arrangement can be made for or what is being done in the steam turbines.

Some constrictions, some padding is provided they are known as constructions. Here we will discuss them later on and the flow of steam or leakage of steam is prevented this, we will discuss later on.

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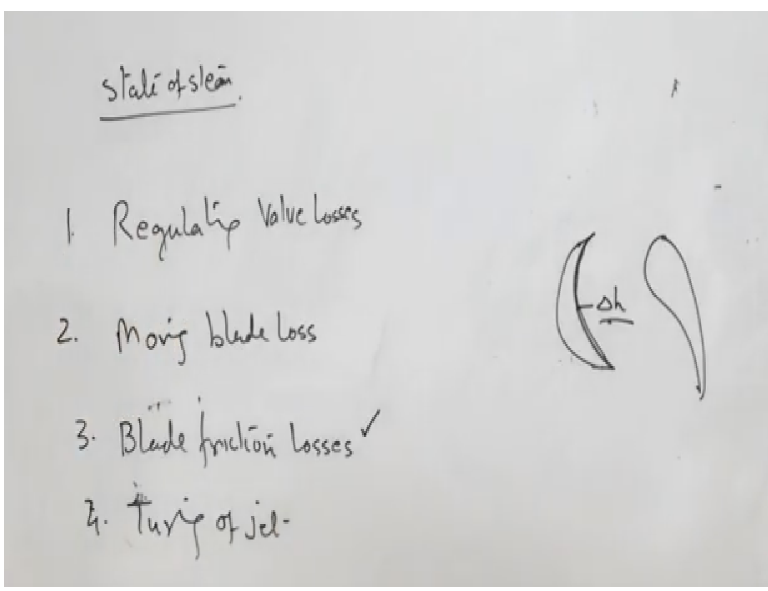

Now another one is blade friction losses when steam is flowing pass the blades I mean the profile time blades in case of impulse turbine or aero file type of blades in case of impulse reaction turbine, the surface of the blade it offers the resistance to the flow or friction between the steam and the blade surface. This also results in loss of energy delta H or loss of energy right. So this is known as blade friction losses so the losses due to turning of the jet when jet or steam jet, when it flows pass the blades.

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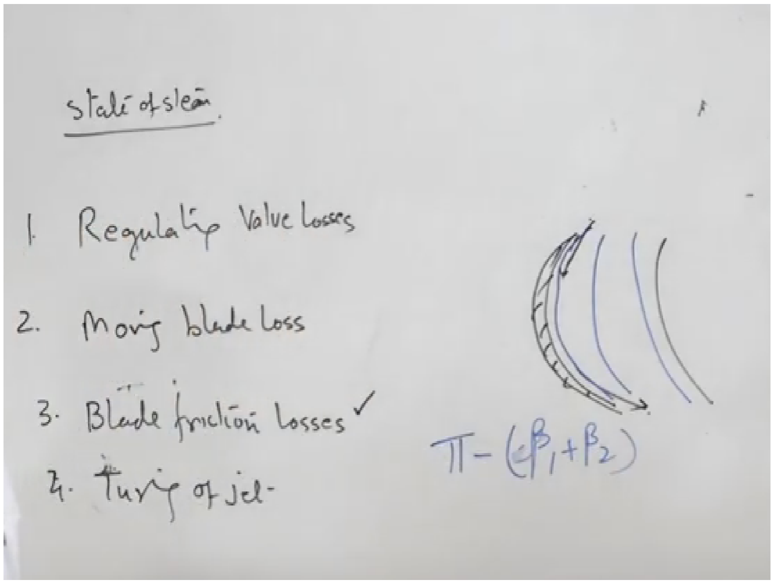

So there is impulse turbine and steam jet is moving over the blades, so it is changing direction. Now it is not a thin line, the entire steam is flowing in this passage. Some part of the steam is in the vicinity of the blade, some part of the steam is in vicinity of blade surface. This is blade, suppose part of the steam is in the vicinity of the blade surface part of this steam will flow like this, because when we do the analyses we take very ideal case.

But in actual practice the path covered from this point to this point will be different for different volumes of the steam. That is one thing, second thing is when there is change in direction losses are bound to happen in actual practice and in this case the change in direction is Pi minus blade inlet angle minus plus blade outlet angle. So lower the value of this higher the change in the direction and more will be the losses in blade passage.

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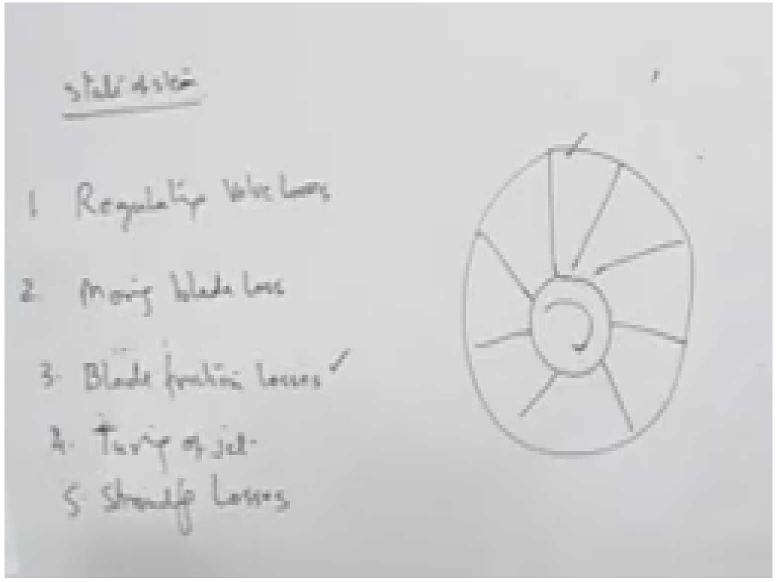

Shrouding losses in turbines is done. What is shrouding? Shrouding is suppose, if we look at the in view of the turbine I am just giving you the estimating view it is going to be like this. There are number of blades attached to the rotor and the rotor is moving with certain rotational speed. These blades are tied together with the help of shrouding and this shrouding also causes interruption in the flow.

So when the shrouding is there the presence of shrouding also contributes towards the losses during flow in a turbine. Third one is disc friction loss, suppose the fluid which ins team it is viscous fluid , it is not a non viscous fluid. So it is a viscous fluid flowing over the blades. So the resistance to flow will be offered it is known as disc friction losses. So these losses will also be there when there is flow of steam over the surface of the blades.

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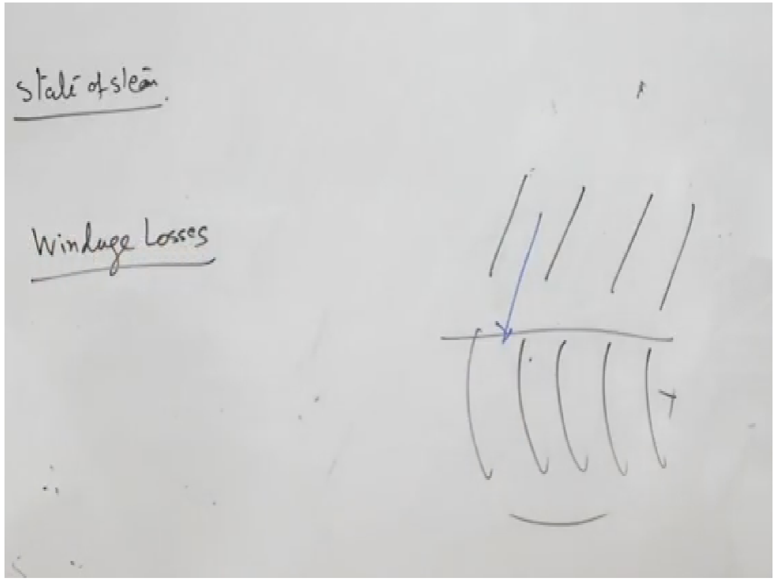

Another type of loss is windage loss now what happens is in high pressure turbine, especially in the high pressure area specially in the impulse turbine, there is limited number of nozzles and the limited number of nozzles all the blade passages are not directly exposed to the steam which is coming from the nozzle. In some of the blade there is partial admission.

This partial admission in the blades is known as windage losses right and we will start with the disc friction loss, there is a formula for disc friction losses in a steam turbine.

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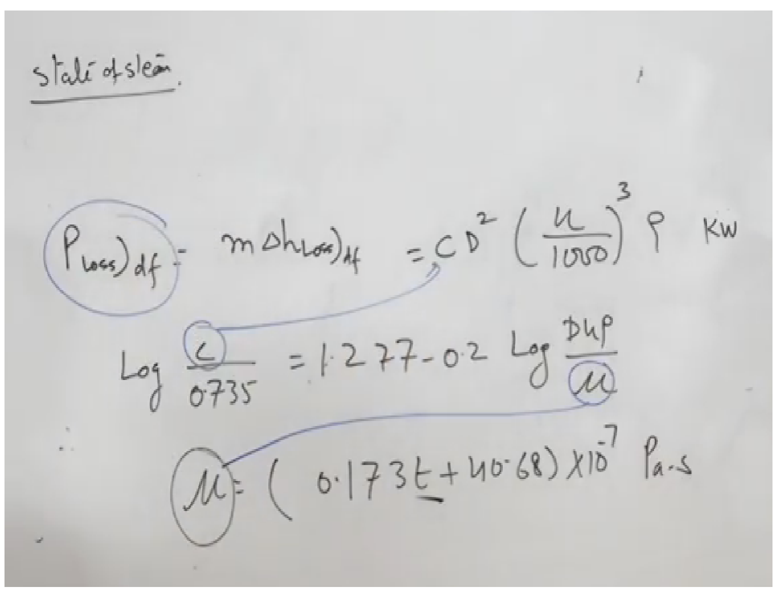

Power loss disc friction = M delta H loss disc friction = C D square U by 1000 cube rho kilowatt. This is empirical relation, so this where Log C by 0.735 = 1.277 – 0.2 Log D U rho by Mu. So from here if we know the diameter of the turbine, peripheral velocity and rho is U by V1, then we can get the value of C provided we have the value of Mu

Mu is the function of temperature viscosity is always the function of temperature and for steam it is taken as 1.173 T + 40.68 into 10 to the power of -7 Pascal seconds. Now here you can see that quit temperature is cost is increasing because if we increase the temperature the viscosity of the liquid will fall but viscosity of the gases will increase.

Now here in the case of steam the viscosity of the steam will increase is a vapor with rise in temperature. So if we know the temperature of entering the steam, we will get the value of viscosity this value of viscosity can be put here and we will get the value of C and this value of C can be put here we will get the power loss in disc friction. Now another case is blade windage losses, I have already explained you.

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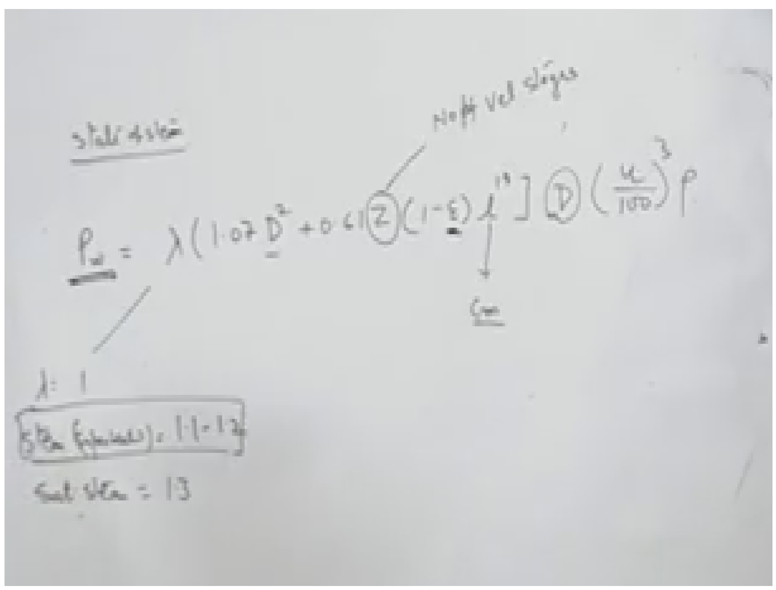

So in this case then again in P windage losses = lambda 1.07 D square + 0.610 Z 1 - epsilon L is to power 1.5 D U by 100 cube rho. It is difficult to remember but this is also an empirical relation where lambda from here is generalized equation. So for here it is one for super heated steam it is 1.1 to 1.2 and saturated steam = 1.3.

So for three different conditions lambda 11.1 to 1.2 is super all natural steam turbine comes this way lambda one. Lambda can for steam turbines because the vapor is always super heated while entering the steam turbine. We can always comfortably take 1.15 average of this. Now this is the mean diameter Z is the number of velocity stages, so number of stages will be there is a ten stages turbine Z = 10 it is a 20 stage turbine Z = 20 epsilon is clearance.

It is for the clearance L is blade height is in centimeters. This has to be remembered otherwise E will be getting all together different results. D is the diameter of the rotor U is the peripheral velocity U is rho is velocity ratio and this will give you the energy loss in windage in clearance losses because in turbine there is clearance at two places. So let us take a case when the impulse reaction turbine.

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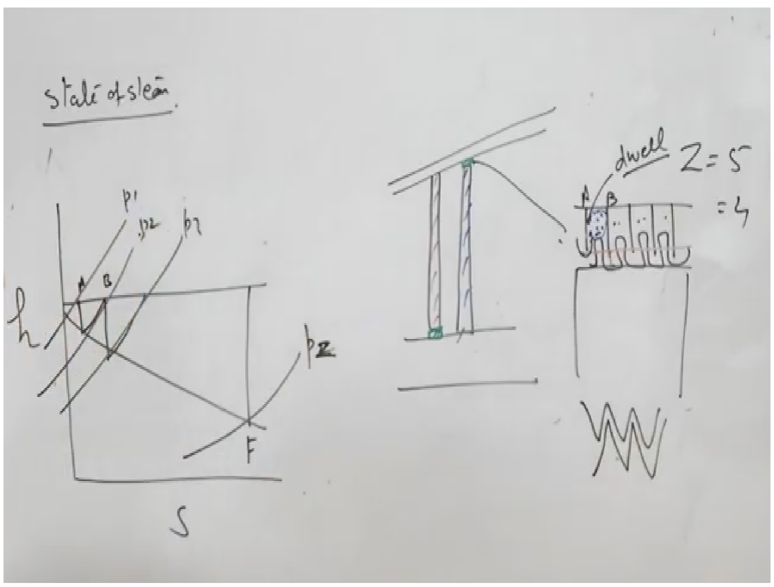

So in impulse reaction turbine the nozzles are fixed in the casing and blades are fixed on the rotor. So these are the blades and this one is nozzle and these blades are fixed on the shaft, there two places where leakage can be take place these places are this clearance and this clearance. So in order to prevent leakage, constrictions are provided. Constrictions are nothing but obstruction suppose, this if you take it here and this is something like obstruction to the flow they are known as constrictions.

So in fact a sort of trundling will take place through this and slowly gradually the pressure will reduce or we can have different configuration. We can step type also constriction to offer more resistance or dual space like this, we can have different type of configuration not like this, we can have different type of configuration but they should not obstruct the movement of the blades if the constriction are obstructing and they are made of soft material.

So if they come in contact with the blades they will wear out what happens if you make closing casing instead of putting constriction, and if blades strikes the blade the entire turbine will be damaged but constrictions are made of soft materials. So even if blade edge comes in contact with the constriction it will wear out the constriction.

Now if we draw enthalpy entropy diagram suppose, they are five constrictions so dwell there is going to be suppose constriction is five, so number of dwells will be four. Dwells means the gaps will be four and in the first suppose, this is A right and expansion takes place in this constriction suppose this is A trundling or expansion takes place. In this case the velocity will increase but when the steam enters here this turbulence.

Because here the velocity is increased but it is confined here again the pressure raises it is not the pressure rises, the energy is regained. Energy is regained and we get a straight B and that is another pressure. This is another pressure P1, let us say this is P2 and straight B. Again the expansion will take place and then again the energy will be regained and then it is P three and this is how the pressure keeps on reducing and at the last stage you will get the final pressure that is P two P, P Z job bhi whatever it is P Z

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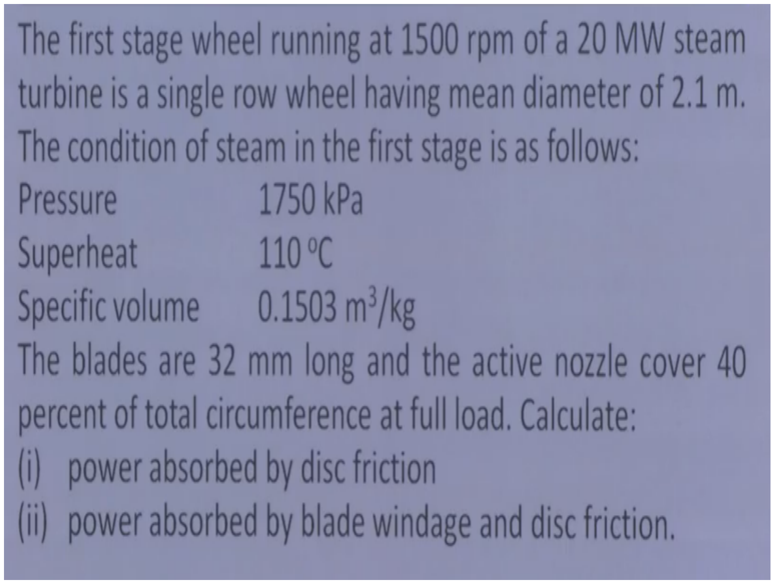

Now we will do a world example for regarding the leakage of energy losses in the steam turbine. The first stage wheel running at 1500 rpm of a 20 megawatt steam turbine is a single row wheel having mean diameter of 2.1 meter.

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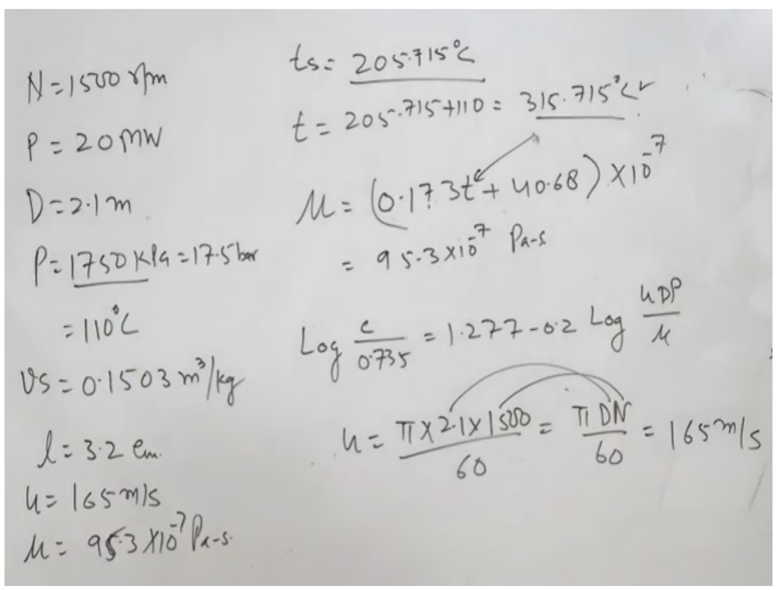

So we will put down the values here N = 1500 rpm and the power is 20 megawatt, mean diameter D is 2.1 meters. The condition of a steam in first stage as follows pressure is 1750 kilo Pascal or 17.5 bar super heat 110 degree centigrade, it is above the saturation temperature degree of super heat specific volume, 0.0503 meter cube per kg.

The blades are 32 mm long L = 3.2 centimeters and active zone covers 40 % of total circumference. At full load calculate power absorbed by disc friction. So first of all we will take pressure corresponding to this the saturation temperature is 205.7715 degree centigrade.

The total temperature is going to be 205.715 +10 it is going to be 315.71 degree centigrade or you can rounded off to 205.7, because third digit accuracy is not required right. So this is the temperature now with the help of this we can calculate Mu. So Mu is 0.173 T + 40.68 into 10 to power -7 at this temperature viscosity of the steam is going to be if we put the value of T from here.

So T from here and then we will get Mu = 95.3 into 10 to power - 7 Pascal, second now that formula if you remember this Log because we need to have the value of C log C by 0.735 = 1.277 - log U D rho by U. So here we have the value of U = pi into D is 2.1 into N is 1500 divided by 60 pi D N. So pi D is to 2.1 is given here and 1500 is also given here.

So this is D, this is N and the value of U is 165 meters per second. So value of U will note down here 165 meters per second, Mu is also there 95.3 into 10 to power - 7 Pascal second.

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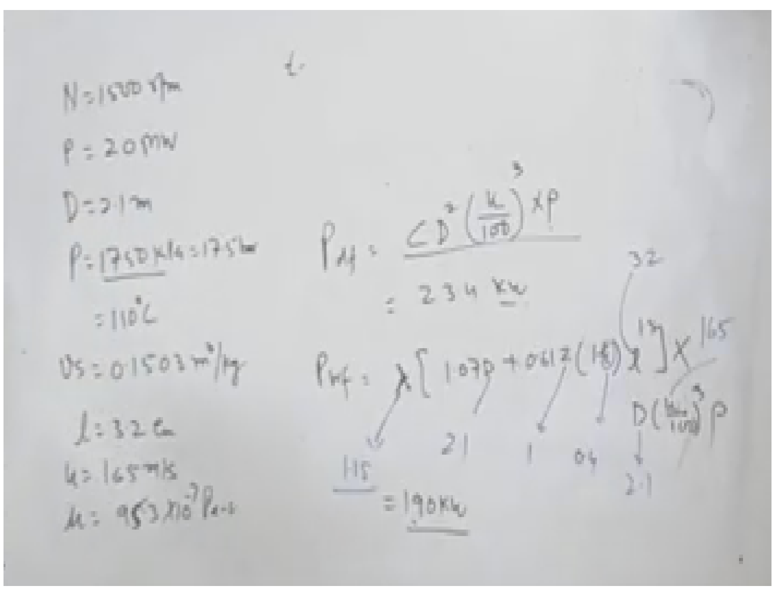

Now we can calculate the disc friction is now = C D square U by 100 cube into rho and now we have the value of U. We have the value of rho C is with us, diameter is with us right. Putting these values here we will get the disc friction that is 23.4 kilowatt, if you compare the output of the turbine it is not very high though in itself 23.4 kilowatt is substantial energy.

Now power in windage is lambda 1.07 D + 0.61 Z 1 - epsilon L is to power 1.5 here multiplied by D U by 100 cube multiplied by rho. Now lambda for super heated steam we can always take 1.15. D is diameter two right .1 meter .6 Z. Z is number of velocity changes, so single rho wheel having diameter.

So number of velocity change is one, this epsilon, this is partial area where I mean this is active zone that is 40 %the epsilon is 0.4 which is covered by the steam and L is the length of the blade 3.2 D is 2.1 U again is 165 right. If you are putting all this values the final expression shall come out to be 190 kilowatt. So this is how with the help of available information for a turbine, we can find the detraction loss where the windage loss in the system that is all for today thank you very much.