**Steam and gas power system**

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**Module No # 5**
**Lecture No # 22**
**Compounding of stream turbines**

I welcome you all in this course on steam and gas power systems, today we will discuss about the compounding of steam turbines. Compounding of steam turbines basically means about the objective of the compounding of the steam turbines is to have the same output with reduced RPM because single stage steam turbine is very high rpm so in compounding the basic object of the compounding is without altering the output of the turbine the RPM of the turbine is reduced so that it can be used for power generation.

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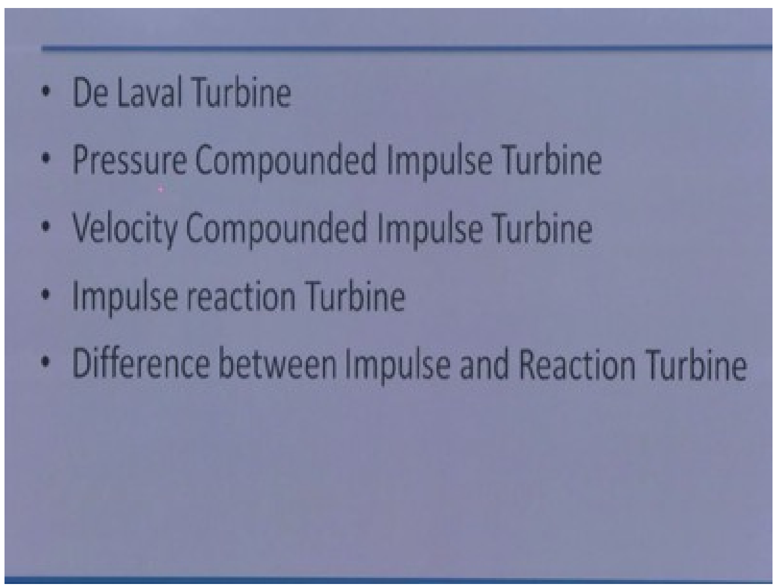


Now before we go for the compounding we will discuss about the De laval turbine first and then we go for pressure turbine compounded steam turbine, velocity compounded impulse turbine, impulse reaction turbine and then we will discuss difference between impulse and reaction turbines. So first of all we will discuss the single stage De laval turbine.

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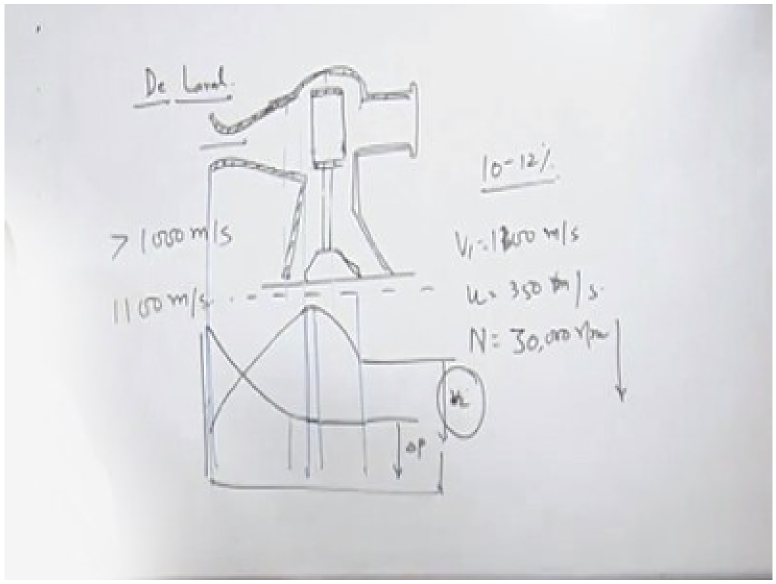


This is a single stage turbine so there is a shaft in this turbine okay and on this shaft the blades are fixed so there is only one row of the blades. So like this, this appears to be rectangle but it is a curved plate or curved blade like this. So when we take an elevation of this it will appear to be a flat plate and the sitting to the blade there is a nozzle normally it is a converging diverging nozzle.

Now this total sends steam to the blade so this a nozzle a converging diverging nozzle right and let us house this and this is exhaust and from this side also it is closed, this side also it is closed okay. So now this is converging diverging nozzle as you know in the converging diverging nozzle the velocity of steam coming out of the converging diverging nozzle is quite large and normally it is it exceeds thousand meters per second.

Let us say normally in De laval type of turbine it is 1100 meters per second right and this steam glides over the blade okay and blade is if the shaft is along the board then the blade is like this and when it glides over the blade it exerts force on the blade and the blade a tangential force is exerted on the shaft with the result and rotational motion because there is number of plates okay because there is series of blades circle facially and axially.

But this is a single stage turbine so there is only one row of blades okay some freshly there are number of blades but actually there is only one row of blade in De laval turbine. And if you look at the variation of velocity and pressure in this turbine, make this half shaft pressure and velocity variation. This is nozzle, blades and there is a vessels between nozzles and the blades, this is a line this is the gap for nozzle and this is for blade right.

So if you look at the variation of pressure so there is a variation in the pressure in the nozzle right from the entry to the exit there is a pressure drop in the nozzle in dresses we do not consider any pressure or velocity loss so it goes on like this and what about this pressure loss in the impulse turbine blade because pressure loss in the impulse turbine blade zero, there is no pressure loss in the impulse turbine blade.

So it is also going to be straight and this is going to be the condenser of pressure, this pressure is condenser pressure. Now regarding the velocity inside the turbine the velocity also here increases in nozzle, velocity of stream because nozzles are basically used to convert pressure energy into the kinetic energy.

So velocity increases in the gap between the blades because it is small gap between the nozzle and the blades so it remains constant here and in the blades the velocity keeps on reducing and here exhaust takes place this is almost this is V2 and in fact a lot of energy is going out with this velocity of the steam it is approximately 10 to 12 % that is the kinetic energy which is going out of this steam first of all.

So this is the wastage of energy so it should be trapped in order improve the efficiency of the turbine its inlet velocity is approximately 1100 is stated earlier also meter per second the velocity U the rotational velocity of the rotor approximately 3000 per hour meters per second and N rpm is 30,000 rpm right. So in de laval turbine, single steam turbine the RPM is 30,000 inlet velocity is 1100 meters per second.

And approximately 10 to 12 % of the kinetic energy is going up with the exhaust so these are the main drawbacks of this single stage de laval turbine. Now in order to improve the working of this turbine first of all we have to reduce the RPM, we have to reduce them to an acceptable value.

Second thing is these losses due to this kinetic energy of steam which is leaving the turbine have to be minimized okay.

So for this purpose compounding of turbine is done so this turbine is used for the smaller power generation but to compounding we can reduce the RPM and we can reduce these losses also. So for the purpose of compounding, we will draw another diagram and this compounded impulse turbine is also known as the rateau turbine.

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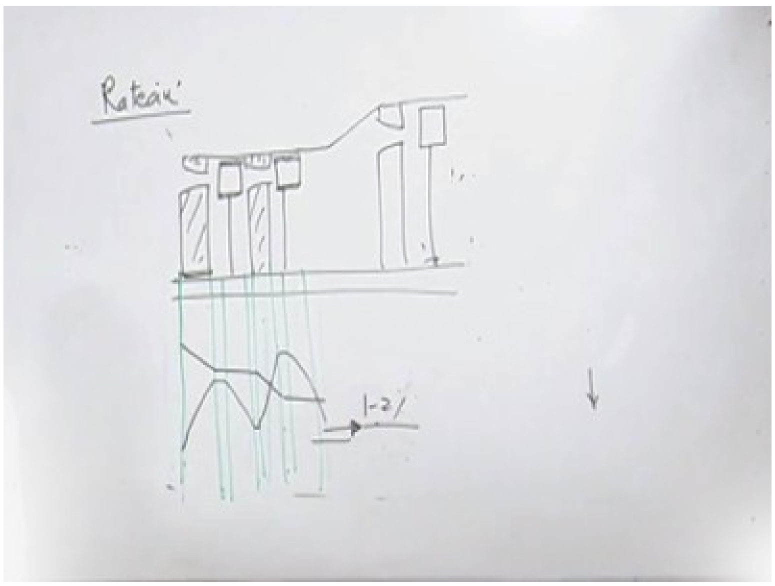

In this turbine the pressure does not take place in a single nozzle so there is a set of combination of blades and the nozzles, so one stage consists of one set of nozzles and blades right. So de laval turbine single stage turbine, so in rateau turbine the number there are number of stages if we depict them pictorially the turbine is going to be like this, there is a shaft on the shafts there are blades first of all we will depict the blades, there are blades right and there are nozzles and there is another nozzle similarly we can have n number of stages.

I mean each stage will consists of set of nozzles there can be n number of nozzles circumferentially but actually there is only one grid of nozzles and one grid of turbine blades right. Similarly we can have number of stages when the pressure is reduced the volume is increased so the size of the turbine is also increased we can have n number of stages here also right.

Now these nozzles these blades are fixed to the shaft and they rotate along with the shaft but nozzles they do not rotate alone with the shafts in fact there is a small gap between this and between the nozzle body in the shaft and at the top they are fixed with the teasing. So they remained stationary only the blades which are fixed on the shafts they rotate with the shafts.

Now here if we draw projections from the nozzles, these are the projections from nozzles ,this one, this one then from the blade then again from the nozzle then again from the blade and so on. Now in the nozzle let us start with the pressure drop so pressure drop in the nozzle is going to be like this it is not linear because the distance is small it appears to be linear but it is not linear then in the races it remains constant because in races we assume that there is no this gap is very small much smaller than which is appearing here.

So it remains constant and now the blade itself there is no change in the pressure because it is the impulse turbine. After the blade there is a races there is no change in pressure then again there is a nozzle there is a pressure drop then again pressure remains constant. So what happens here the entire pressure drop does not take place in a single nozzle it is being splitted in number of stages since the pressure drop is being splitted in number of stages the steam entering the first stage of the blade will not be the velocity of this steam will not be very high like 1100 meters per second.

So it is going to be low because pressure drop is low right and what about the velocity now we will start with the velocity in the first set of nozzles the velocity will increase you know there is a drop is pressure velocity will rise in races the velocity will remain constant right and then in the blades the velocity will fall. And then again it will remain constant in the races space then again in the nozzle it will raise right remain constant and it will fall.

So velocity will keep on rising and falling, pressure is simply treated in number of stages the net effect is the RPM of the turbine is reduced output is same but the RPM of the turbine is used and this turbine becomes more useful for power generation and when we talk about the carryover losses carryover loses means losses or the kinetic energy being take away by which is leaving the turbine these loses are only 1 to 2 % very less in comparison to the de laval turbine.

So this is the pressure compounding of turbine pressure compounding means pressure drop does not take place in single stage but it is splitted in number of stages. Now another is velocity compounded in turbine the velocity compounded turbine is the Curtis turbine okay.

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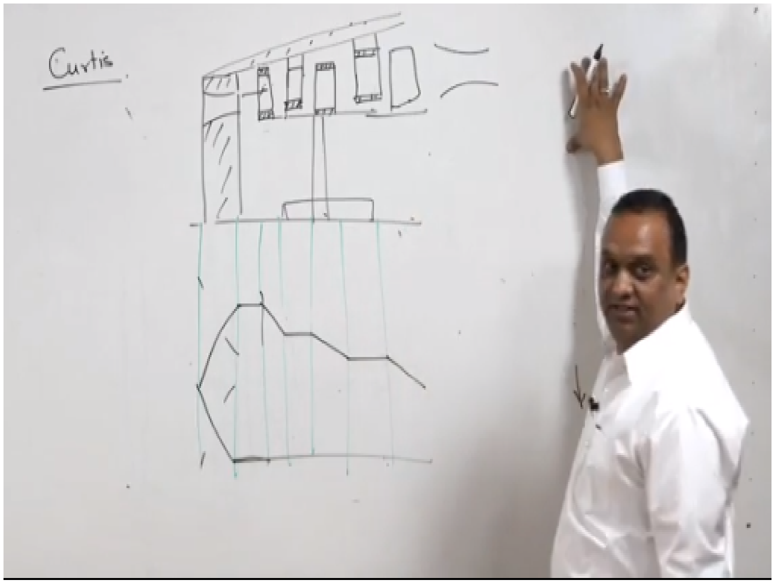


So Curtis turbine is the velocity compounded turbine in this turbine the velocity is splitted in pressure compounding turbine the pressure is splitted so in a velocity compounded turbine there is only one nozzle of the shaft. On the shaft there is only one nozzle there is a shaft and there is only one nozzle and this is the diverging passage because the specific volume of steam is increasing.

So it is a diverging passage and in this diverging passage we have blades fixed on the rotor so there are blades to give, there are fixed blades there are two types are blades here moving blades and fixed blades. So moving blades are in contact with the rotor or fixed with the rotor and fixed blades are fixed with the housing so there is another fixed blade.

Now I will tell you the purpose of having fixed blades in fixed blades right so and then there are again will draw the projection from here, nozzles and then moving blade, fixed blade, moving blade fixed blade so there is only one nozzle here and in this nozzle as in case of other nozzles there is a pressure drop and there is a rise in velocity of the steam. Pressure drop takes place in this stage only in Curtis turbine in remaining stages there is no pressure drop.

So pressure remains constant after the pressure drop the pressure remains constant or we can swap them for the sake of convenience so this is pressure drop and pressure drop remains same then the pressure remains same in remaining stages in Curtis turbine. And regarding the velocity first there is a rise in velocity because the purpose of the nozzle is increase the velocity then there is a resist.

So in the resist the velocity remains constant here there is a drop in the velocity guide in blades there is no change in the velocity and then again there is a drop in the velocity then guide veins there is no drop in the velocity. So in velocity compounded turbine we can have another I mean another blade here so then again there is going to be a drop in the velocity. So in the velocity compounded turbine the entire velocity is splitted into several stages that is why it is known as velocity compounded turbine.

And the previous turbine which was rateau turbine, in rateau turbine the pressure was splitted into the number of stages and okay after this we will take up velocity and pressure so we can have combination also we can have the combination of velocity compounding and pressure compounding. So then these stages are velocity compounded then again certain stages are velocity compounded and it would be there is a pressure drop.

So we can have similarly we can have another nozzle here for example another nozzle then velocity compounding then another nozzle velocity compounding that type of arrangement is known as pressure and velocity compounding of impulse turbine. Second type of turbine is impulse reaction turbine in impulse reaction turbine the output is generated not only by the impulse of the moment of the steam or rate of change of momentum of the steam.

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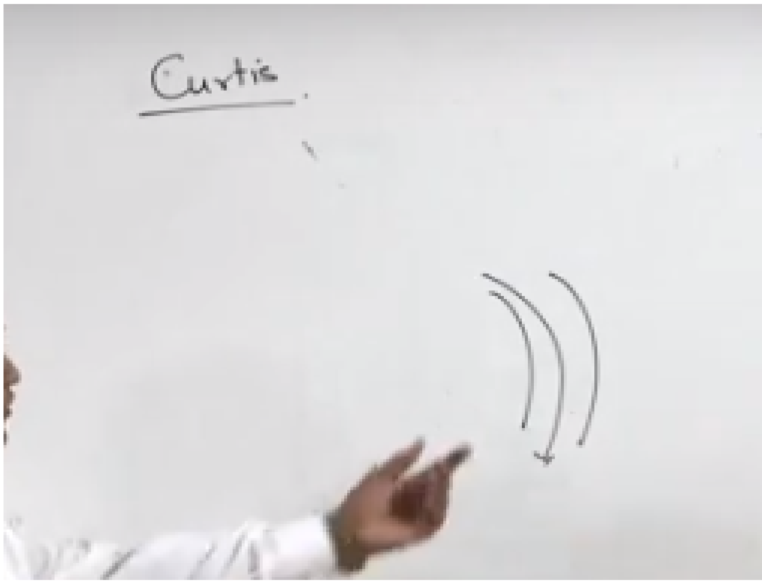


But also expansion of steam or pressure drop of steam in the blade passage pressure drop of steam in blade passage is not uniform okay so expansion of or the pressure drop of steam also takes place in the blade passage and the power is generated and for impulse reaction turbine again and the blades are there are two types of blades profile type of blades and aero foil.

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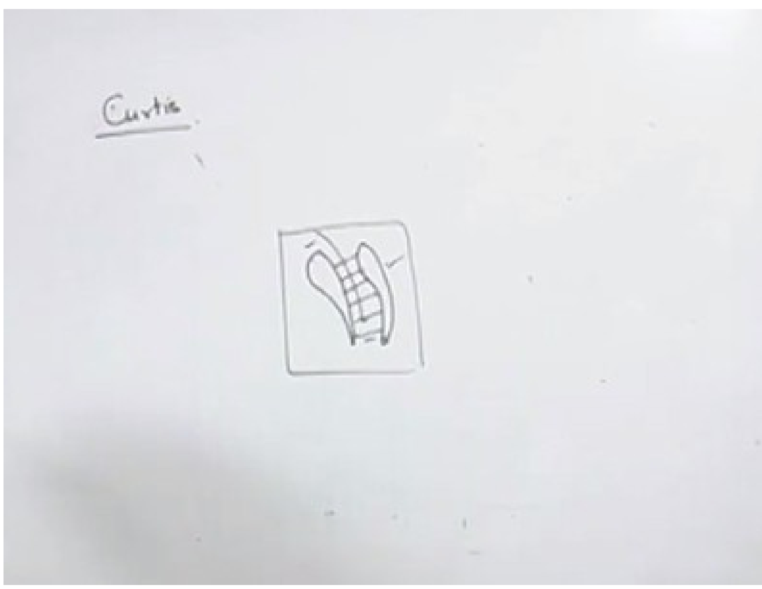


This impulse reaction turbine they have aerofoil type of blades we will discuss them in details in subsequent lectures we will discuss this impulse reaction turbine in details but the shape of blades in impulse reaction turbines is aero foil type. And there is a change in cross section area of the passage and that is how the reaction is created in impulse reaction turbine. So this turbine is also having stationary blades moving blades since pressure drop takes places in both the cases.

Stationary plates also and the moving plates also and there is a special type of turbine which is known as partial turbine. In partial turbine 50 % in enthalpy drop takes place in moving blades. So suppose they are steady stages so in each stage it is 50% in moving in this 50% in stationary stage. So this is how I mean reaction turbines are compounded because they do not have nozzles they have only passages.

One grid is for stationary and another is for moving pressure drop takes place in both these stages right so we will discuss this impulse reaction turbine in the subsequent lectures. Now difference between impulse and reaction turbines

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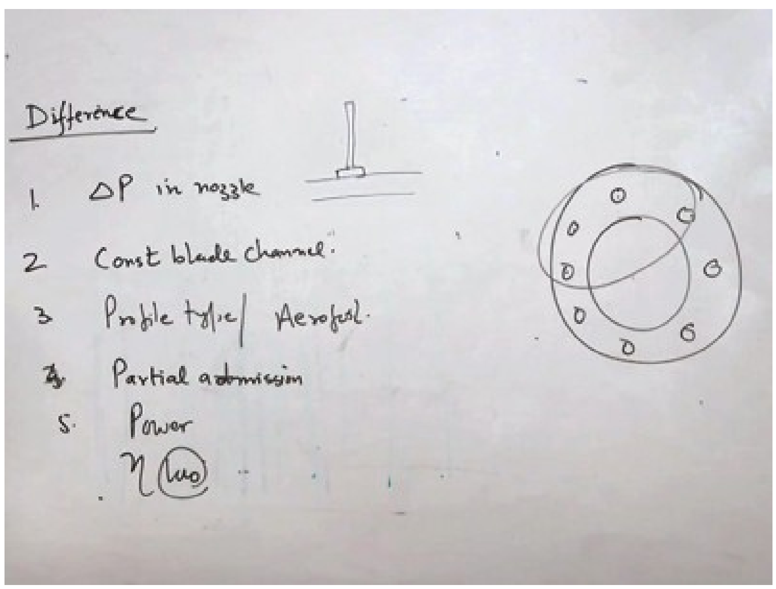


In impulse turbine pressure drop is in nozzle only impulse reaction turbine they do not have any nozzles and pressure drop takes place in the entire length of the turbine or along the axis of the turbine rotor. In impulse turbine there is a constant blade channel so there is no pressure drop in impulse turbine in reaction turbine there is a variation in the cross section in the blade channel that is why there is a pressure drop in reaction turbine.

Third is they are profile type of blades in impulse turbine and in reaction turbine they are aero foil type of blades and this causes pressure drop in the channels in impulse reaction turbine. Fourth one is in impulse reaction turbine partial admission in the turbine for example suppose there is a side view of the turbine so we can have nozzles at different locations so we can activate only these nozzles.

We may not supply steam to these nozzles so partial admission for the sake of controlling the output of the turbine is possible in impulse turbine but partial admission. But this is not possible in impulse reaction turbine. Because in impulse reaction turbine we don't use nozzles, nozzles are not being used so here there is a diagram consist the nozzles grid of nozzles a grid of nozzles and we can partially supply steam to these nozzles or we can select number of nozzles to which the steam can be supplied so this is possible in impulse turbine.

Fourth is power developed in impulse reaction turbine is more so power developed in impulse reaction turbine is higher than the impulse turbine and this impulse turbine if you look at the size of the turbine so impulse turbines occupies less space if you compare with the impulse reaction turbine but their efficiency is low efficiency of impulse turbine is less than the efficiency of an impulse reaction or bit less than the reaction turbine.

And so these impulse turbines are used for low power generation but the benefit of these turbines is their blades are easy to manufacture they are lighter in weight and they causes less stress on those blades are fixed on the rotor they are fixed on the rotor. So if they are light in weight easy to manufacture they are fixed on the rotor and they cause comparatively lesser stress in the rotor so there is a benefit of impulse turbine if you compare with reaction turbine. In the next lecture we will start with the analysis of a power generation in impulse turbine.