Applied Thermodynamics
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Steam Power System
Lecture - 05
Introduction to Steam Power Plant

Good afternoon. I welcome you all to this session of Applied Thermodynamics and in this course there are 2 parts, one part will be discussed by Professor Niranjan Sahu.

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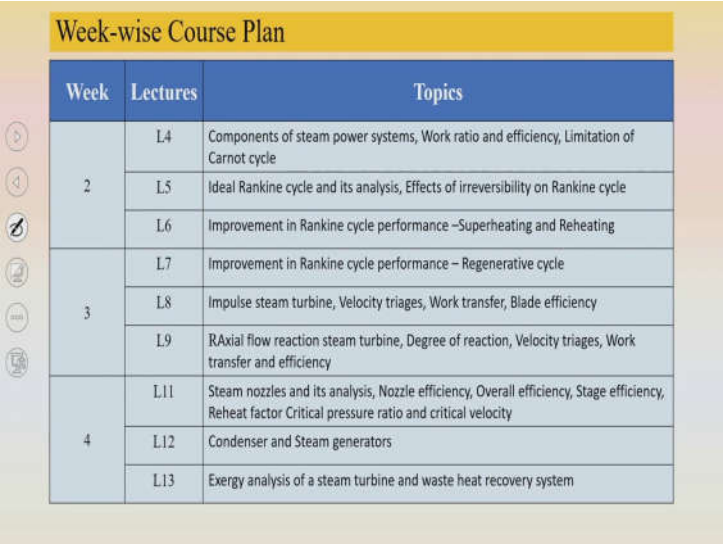

And I will be focusing on the power cycle and this is week wise course plan. I have described several topics those will be discussed in this course and rather lecture wise topic.

So, in the first class you can see that we will be discussing about components of steam power system, then different other aspects like work ratio efficiency and finally we shall discuss about the limitation of Carnot cycle. But before I go to discuss about limitation of Carnot cycle let us first discuss about what are the different components in a steam power cycle.

If you would like to analyze this steam power cycle we need to map those processes in a thermodynamic plane or ordinary diagram and then the concept of cycle will be coming

and then we will discuss about different cycles which are known as Ideal cycle, Actual cycles etc.

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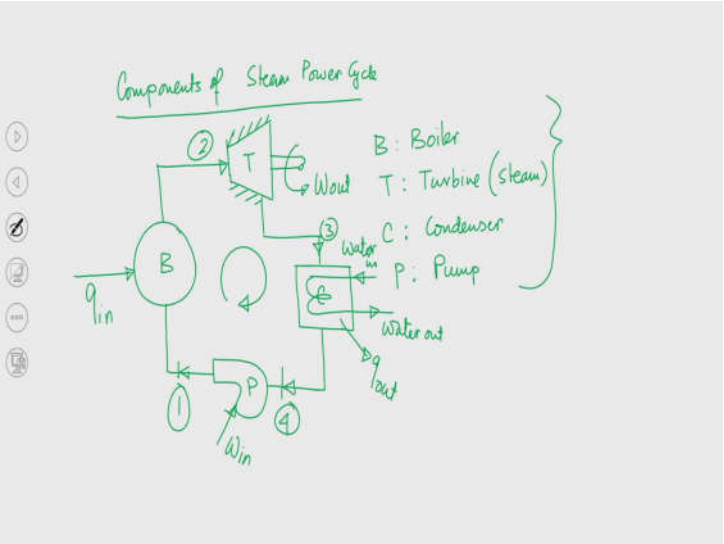

So, just for the, you know for this particular lecture as I mentioned, we will be discussing about the components of steam power cycle. Now I am sure that you all have studied thermodynamic course and by this time you know the concept of cycle and that is what was discussed in the basic thermodynamics course.

So, you know that I have written steam power cycle, the power cycle can be operated as the vapor power or gas power cycle depending on the working substance that is used to operate the cycle.

So, now today we will be discussing on the steam power cycle as the name suggest it is the power cycle in which the working substance is steam or water or steam water mixture.

So, let us briefly review what are the different components through the line diagram, it is really impossible to discuss all the components, you can understand that when you talk about a steam power plant you might have visited different steam power you know plants rather different plants of NTPC also there are different plants operated by State Power Board.

Now, just for the quick understanding if we try to draw the line diagram and through which we will try to discuss different components at least the components, which are major components. So, this is basically a line diagram of this steam power circuit steam power plant. As I said that there are several components present in the circuit, but I have drawn 4 major equipment which are there. What are those?

See I have given name B which stands for boiler, T for turbine definitely it is steam turbine not hydraulic turbine, then C for condenser and P for pump. So, these 4 major equipment we have identified in this line diagram. So, I mean as I said there will be different other components, but those components are not major component.

We will discuss that in addition to these 4 components we need to understand one or two; though they are minor component, but still they are you know operational principle their significance in the context of this power cycle we will try to understand.

So, basically you can understand in this circuit there are 4 major components we have depicted. First one if you try to start from this one that is the extreme left that is boiler then turbine, condenser and pump, these 4 components either they are heat interacting or work interacting components. So, basically what is done you all know but still I need to describe that in this particular component water is supplied and that water upon receiving heat from external source q_{in} is getting converted into steam.

The steam which is produced in the boiler whether the steam getting produced is wet steam or dry steam that is different issue altogether we will discuss in this course. But, for the time being at least you should know the steam which is producing in this boiler is taken to another device which is turbine.

Now, in this turbine when steam is allowed to flow through the turbine. As I said that there are several other small components, steam will not be allowed directly to go to the turbine rather steam will be taken to steam will be taken through nozzle first and then when steam is flowing through the nozzle its kinetic energy will be increased and when steam will be coming out from the nozzle it will having high kinetic energy.

That steam having high kinetic energy will strike the turbine blade and by virtue of momentum transfer the turbine blade will rotate and we will be getting work output from the turbine shaft. So, this is turbine shaft; so this is work output.

As I said that these 4 components either they are heat interacting component or work interacting component. So, for the time being at least we have discussed these two components that is boiler and turbine, we have seen this boiler which upon receiving heat from external source is responsible for producing steam.

So, water is circulated through the boiler heat is supplied from external source and upon receiving heat, water is getting converted into steam. So, this is basically heat interacting device. So, no work is produced in the boiler, but we cannot say because we will be discussing slowly in this course. Basically in this context let me tell you that first law of thermodynamics, second law of thermodynamics will be useful to analyze the processes.

So, basically we are supplying water to the boiler and water after receiving heat is getting convert into steam. So, there is a process that process we need to identify which process it is, whether the process is a constant volume process that we have understood from our thermodynamics course or the process is constant pressure process that we need to identify. And not only we have to identify and then we have to map that process in thermodynamic plane.

So, now when steam is coming to the turbine through steam nozzles, that steam which is ejected from the nozzle is having high kinetic energy and that steam is striking the turbine blade and we are getting work output by virtue of momentum transfer turbine blades which are mounted on a shaft. So, steam having high kinetic energy will strike the turbine blade.

The blades are mounted on a common shaft. So, shaft will rotate and from where we will be getting work output, so this is again work interacting device. So, it is assumed that when we will be discussing about thermodynamic laws applied to this turbine. So, this is insulated no heat is getting lost to the surrounding theoretically. So, basically this is work interacting device. Now here fluid does work on the rotating part of the machine right.

So, in the turbine what is done; high pressure high velocity steam is taken to the turbine through nozzle and while steam is expanding through the turbine it does work on the rotating part of the turbine and that is why you are getting work output. And this shaft on which the turbine blades are mounted will be connected to a shaft of an alternator, from there we are getting electricity and that is what is the concept of this thermal power plant.

Now, after doing some work steam is taken and it is taken to another device or another component which is condenser. Now question is in this context I have drawn one symbol that is cyclic cycle. So, basically all the processes are occurring in a cyclic manner.

So, the purpose of keeping this condenser is to reject heat, second law of thermodynamics that we have studied puts a restriction that if you need to operate this system in a cyclic manner then there must be heat rejection. So, we are having heat addition to the boiler and we have studied from second law of thermodynamics that there must be heat rejections to operate the system in a cyclic manner.

So, if you would like to operate this in a cyclic manner following thermodynamic cycle that we will be discussing soon. So, there must be heat rejection and that is why the steam after doing some work in the turbine is taken to the condenser in which heat is getting rejected so this is q_{out}. So, we can see that we are supplying steam to the boiler out of which some part of the steam is getting rejected in the condenser. What is done here?

Basically cooling water is circulated, so basically this is water in and this is water out. So, while steam is coming out from turbine it is taken to the condenser and while passing through the condenser, the cooling water is supplied as a result of which steam which is leaving the turbine is having still enthalpy, some amount of heat.

So, that heat should be rejected to this water and that water will be taken either that water will be discharged to the nearby lake ponds or sometimes you might be familiar that this water is again taken to another device that is called cooling tower for the cyclic operation.

Now, this is q_{out} and so after rejecting heat we are collecting condensate, so that is again water. So, basically when steam is passing through the condenser it is rejecting heat to the cooling water and that condensate that is nothing but water is taken from the condenser and pumped back to the boiler.

So, again the purpose of pump is to supply condensate which is collected from the condenser to the boiler and condenser pressure and boiler pressure these two pressures are not same. So, that is why the pump is there because we need to raise the pressure of the condensate.

So, basically this pump is there, again we need to operate the pump we need to supply work. So, in the beginning of this class I told you two times if I can recall correctly that these devices are either heat interacting or work interacting devices.

Now, you can see boiler is heat interacting device, turbine no heat loss. So, only we are getting work output, so this is the work interacting device. Condenser again there is no work output, but only we are getting heat rejection heat interacting device. To operate pump we need to supply work now we need to give work input work as input. So, this is work interacting device.

So, this process is occurring in a cyclic manner and that is why I have given this cyclic symbol. So now, what I would like to discuss because today is introductory class now I would like to discuss two important thing. In fact, I will be discussing the first and second law applied to these you know devices to analyze. At least we have identified that the working substance here is steam or steam water mixture.

So, water is pumped to the you know boiler and that water is getting converted into steam and that steam does work on the rotating part of the turbine and we are getting work output. As I told you that shaft will be connected to a shaft of an alternator and from there we will be getting electricity. And after doing some work that steam is taken to the condenser, wherein upon rejecting heat we are collecting condensate and that condensate is again pumped back to the boiler.

So, basically what we can understand there are several processes. So, here the pumping process we are raising the pressure of the water. So, the condensate which is collected from the condenser is having low pressure and to build up pressure of that condensate and that pressure should be equal to the boiler pressure. So, the pump should be responsible to rise the pressure of the condensate to the boiler pressure and that is why you need to provide input work.

So, this is basically you can see there is a process in the in a pump. In the boiler what is done water upon receiving heat it is getting converted to steam. So, there is again a process and where steam is collected from the boiler taken through the nozzle and finally it enters into the turbine. So, again there is a process inside the nozzle as well as inside the turbine.

And finally, after doing some work steam which is coming out from the turbine is having still some enthalpy, that enthalpy we need to reject. So, that enthalpy is not usable enthalpy knowing fully that we cannot utilize it. So, we are supplying heat to the boiler at the cost of that heat input we are getting some amount of work output.

But you can understand this work output is not equal to the heat input and that is why the restriction of second law of thermodynamics. So, there must be some amount of heat to be rejected and that is what is done inside the condenser. So, basically what we have seen that there are several processes.

So, if we need to analyze the performance of this steam power cycle, basically this is the line diagram and all steam power plants are operated following this line diagram we will see soon that there are different modification.

So, but still the basic concept is like this. Now if we try to analyze the thermal performance of the steam power plant then at least we have identified several processes, which are occurring inside a particular component and all those processes constitute together are thermodynamic cycle and that those processes should be mapped in a thermodynamic plane or ordinary diagram to understand to calculate the overall efficiency of the power plant.

And if we need to do that what we need to know we need to know the basic of thermodynamics, the basics of thermodynamics that we have studied that is first law, second law.

So, whether the processes are steady state steady flow processes can you apply the steady state steady flow process assumptions applied to boiler, turbine, condenser and pump. So, those part we will be discussing slowly, but for the time being at least in today's class I would like to discuss another important point. What is that?

So, basically you have studied I mean thermodynamics. So, I have introduced one word that is called cycle right. So, a common question that why do we need to have this condenser, instead of keeping this condenser why cannot we use the total enthalpy of the steam inside the turbine and if we can then perhaps the work output can be increased right.

So, instead of rejecting certain amount of heat in the condenser why cannot we use that amount of enthalpy or that amount of energy to obtain equal amount of work inside the turbine that we cannot.

So, the question is if you need to operate the system in a cyclic manner then what will happen? Second law of thermodynamics puts a restriction that there must be a place where heat should be rejected and that is why that this is there.

Now, our objective should be so if we need to operate in a cycle whether it will be following a thermodynamic cycle or in a mechanical cycle that we will be discussing, there must be a place wherein some amount of heat should be rejected. So, heat is supplied through the boiler and heat is rejected in the condenser.

Now, I have introduced that the system should be operated following a cycle, whether the cycle is a thermodynamic cycle or mechanical cycle. Now question is here the cycle is thermodynamic cycle.

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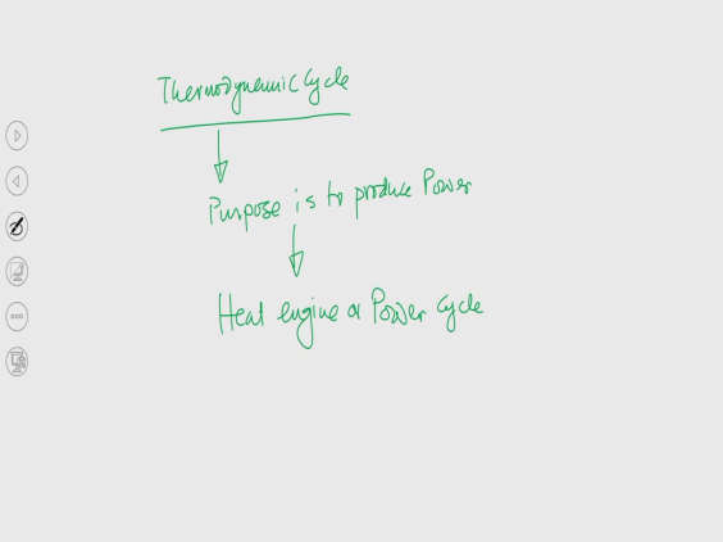

So, I am using the word thermodynamic cycle. So, as I said you that the purpose of a thermodynamic cycle is to either produce power or produce refrigeration. If you need to produce power that is known as heat engine or power cycle and that is what I have written in the previous slide that is steam power cycle. So, using steam as a working substance we are trying to produce power and that is why it is power cycle.

So, the purpose of a thermodynamic cycle is to either produce power or refrigeration. If it is to produce power then it is called as heat engine or the power cycle, so this is the power cycle. So, thermodynamic cycle purpose is to produce power and if the purpose is to produce power then it is called heat engine or power cycle. And now we have come to this point that is heat engine.

So, if it is heat engine now an engine operating in a cyclic manner there must be a sink wherein heat should be rejected and that is why this is there. Now question is can I call it a thermodynamic cycle? Yes. So, this is a closed cycle; thermodynamic cycle is essentially a closed cycle wherein the working substance is brought back to its original position.

So, if you can call it thermodynamic cycle this is a essentially a closed cycle that we can see from this schematic depiction, not only that the working substance mass as well as composition is brought back to its initial state at the end of the cycle. So, if we start the cycle from state 1, so we are supplying water into the boiler that is thermodynamic state at point 1 is the liquid water.

Now, after completing the cycle we are again getting water, so that means it is a closed cycle and the working substance mass as well as composition of the working substance is brought back to its initial state at the end of the cycle.

So, basically thermodynamic cycle is essentially a closed cycle that is working substance undergoes a series of processes and at the end of the cycle the mass as well as composition of the working substance is brought back to its initial state. So, that is why it is called thermodynamic cycle.

You will be studying in this course that there are different other cycle like auto cycle, diesel cycle, dual cycle, those cycles are not thermodynamic cycle rather those cycles are called as the mechanical cycle.

So, with this I stop my discussion today and we will be discussing several other issues related to this line diagram and a few important definition in the context of the cycle those will be very much important to understand the thermal performance of the steam power plant. So, those part we will be discussing in the next class. Thank you