MARINE ENGINEERING

By

Prof. Abdus Samad

IIT Madras

Lecture23

Rankine cycle

good morning everybody today I am starting the topic of marine boilers first I'll discuss general marine boil boiler aspects then I'll go towards turbine and we'll solve some problems we'll discuss different issues a different components and if some calculations also will include in this uh this week lecture week four so first When you discuss marine boilers, first you have to see the Rankine cycle. Rankine cycle is like this. You have one boiler.

I am just drawing like block diagram. Then boiler will be producing steam. Steam will go to turbine. So, turbine, from turbine steam will be coming out, low temperature, low pressure turbine will be coming out and it will go to condenser, condenser. Then from condenser it will go to pump, pump to boiler.

This is a sequence. It will be happening in any steam turbine system. Steam turbine, it is being used for your locomotive application. For example, you can see this heritage train, a ship. Previously, people used to say it like a steamer.

Steamer means it will be producing lots of steam and steam will be driving a marine engine. that is why they called it steamer. Now, those steamer engine, the steam produced engine is being replaced by diesel and other operated engines. And if you see train in India, previously all trains were run by steam engine, now gradually those replaced and now only heritage trains are there which are run by your steam turbine system. Now, the thermal power plant, like if you go to NTPC website, National Thermal Power Corporation, they are running all their systems, especially coal fired systems using your Rankine cycle.

I have drawn one simplest Rankine cycle diagram. It will be having one turbine. turbine will be producing work output. and boiler will be giving lots of heat. heat given to water to produce steam.

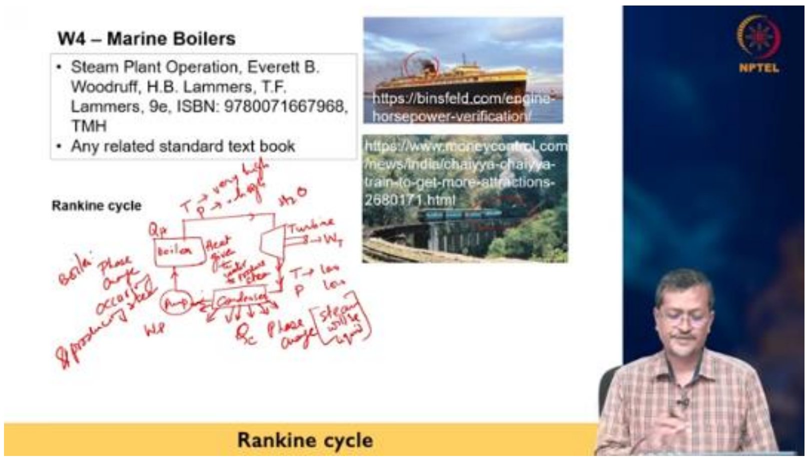
in boiler, you are boiling water and water is taking lots of heat. When it is getting lots of heat, it will be creating steam, superheated steam or saturated steam or maybe unsaturated steam. that high pressure, high temperature steam will go. after boiler, the temperature T will be very high. Pressure also will be very high.

After turbine, your temperature will be lower, pressure also will be lower. after turbine, to pump the pressure will be same actually because turbine and condenser condenser actually one pipe you i have already discussed during heat transfer calculation that heat transfer lectures that condenser actually lots of pipes will be there and in pipe heat will be through the pipe heat will be transferred so because the steam temperature high ambient temperature is lower so heat will be going out to the ambient heat will be, so I can write Q, Q cold or low temperature and boiler is giving Q high temperature and pump WP, pump is taking energy and it is giving to fluid. So, from where it gets energy, it will be getting energy from the turbine directly or it will get energy from any electrical source or any other fuel will be burnt and pump can be run. this is the function of Rankine cycle.

Rankine cycle will be producing steam, this will be going to turbine system. turbine system will be releasing that steam low pressure, low temperature that will be going to condenser. Condenser, there will be phase change, phase change will be occurring. steam will be liquid, will be liquid again in condenser and that liquid or water because this is water cycle or H_2O cycle. water would be pumped, liquid water will be pumped to boiler and boiler again it will be producing steam.

When it is producing steam, it will be high volume high temperature high pressure when pump is working pump will be working at very low volume because already is liquid liquid is having lower volume and it is working at lower temperature also even lower pressure also and boiler phase change occurring so phase change occurring in boiler okay and producing steam and producing steam and the pump is only delivering fluid or adding delivering fluid and adding energy to the fluid so already we discussed the pump will be adding energy so here we are using one pump so that pump can be like it can be centrifugal type pump or it can be jet type pump jet pump i'll discuss later a boiler it is also having heat exchanger inside boiler there will be heat exchanger lots of pipes will be there so Whenever heat comes, heat will be going through the pipe and water inside pipe would be boiled. And finally, the boiled steam will get more heat and it will go to superheated condition.

The superheated steam will go to the turbine, the turbine to the condenser, condenser to the pump. This cycle will be going on continuously. I will draw the cycle again boiler, then boiler to I said turbine, this is my turbine, then turbine to condenser, condenser it is coming, condenser to pump, pump to boiler. this cycle will go on. now what is happening i will put some number from number I will start from boiler inlet pump inlet here one two three four okay now this whole cycle can be represented in ts diagram temperature entropy diagram so



Previously, I told TS diagram will have one vapor envelope. So, this is called vapor envelope. And inside normally two phase will be there. liquid plus steam, liquid water maybe, liquid water plus steam will be there. And this side, this is called superheated zone.

is called superheated zone and this is liquid zone. So, left side of this envelope is liquid, pure liquid will be there, the right side will be superheated zone, in between there will be liquid and steam. and this curve is called the saturation curve vapor envelope is called saturation curve saturation okay so if you take certain fluid if is that fluid property lying on the curve so it will you can say this is a saturated fluid okay if the fluid inside this vapor envelope it's called unsaturated so this area will be unsaturated okay if the fluid property lying on the curve, so it will be saturated. Now, I want to represent this whole steam cycle on TS diagram, S means entropy, this T means temperature.

I will draw the TS diagram again TS and vapor envelope again I will draw and my loop starts from 0.1, 0.1 will be left side liquid I said so liquid vertically going up it is going to 2 You take certain amount of liquid, you are increasing energy, so temperature will be rising. temperature rising, then after that 1, 2, 3. And 2 to 3, boiler will be heating water. Then what will be the changing phase?

It will be steam. Steam 2, it will be superheated steam. Then 3, boiler exit. Then again it will be going down because of turbine work. 3 to 4.

4 to 1 will be mild. I have to put the arrow direction. whenever you are drawing the Rankine cycle, so you have to draw the whole diagram and proper nomenclature and direction also should be given. For example, one if you put in wrong direction or wrong place, so your whole cycle will be wrong, okay. So, here 1 to 2 in TS diagram it shows pump.

2 to 3 it is boiler. pump adding energy to fluid as per definition I already told. Boiler adding again energy to the fluid and making steam. And 3, 2, 4, it is turbine.

What is it doing? It is extracting energy. So, if you have any steam turbine, you can see any locomotive or any steam turbine, National 3 to 4 turbine it is extracting energy and 4 to 1 condenser. So, what it is doing?

It is releasing heat from steam and making liquid. liquid water. Now, we can see 1 to 2 this if you see vapor envelope line, I am just making thicker line this vapor envelope left side. this is liquid side. the point 1 is on this liquid line.

that means the pump will start when fluid steam becomes liquid and condenser will give liquid to the pump, pump will not handle any gas. Now, the pump will be adding some energy, it will reach 2. we are assuming this is entropic process. This is the ideal Rankine cycle. I am drawing ideal Rankine cycle.

Practically, there will be some deviation, later we will discuss. the ideal Rankine cycle will have 1 to 2 isentropic processes. 1 to 2 pump adding energy in ideal cycle, 1 to 2 ideal cycle, it will be isentropic. isentropic means entropy not changing but you ask me what is the practical thing so practical thing will be like this envelope and ideal this one practically we have to give more energy actually so my curve will like this okay instead of two i'll get two dash i'll have to add more energy pump will take more energy now two to three what is happening 2 to 3, I can put like 2a, b, so 2 to 3 if you see, first I will say 2 to 2a, 2 to a, so 2 to actually sensible heating, sensible heat addition, you got water at 2

pump gave some water, maybe say 40 degree centigrade temperature, but it must reach to 100 degree centigrade, then it will start boiling at one atmospheric pressure. So, to reach 100 degree centigrade at one atmospheric pressure, you have to give certain amount of energy. that is called sensible heating. So, using one thermometer, you can measure that one. 2 to A is sensible heating process and A to B, phase change occurring.

A to B because inside vapor envelope, so lots this zone phase change will be occurring. liquid to steam it will be forming, when you are reaching to B you are getting liquid to steam. Now, B to 3, B to 3 what you are getting? B to 3 actually At B, B is actually unsaturated, this is saturated, saturated steam, saturated steam at B, at B. And A is saturated liquid, saturated, point A is the saturated liquid point, and point B is the saturated steam point.

at B. So, B to 3 what is happening? This is called a superheated zone. Superheated steam. When you are reaching to 3 from B to 3, you are creating superheated steam. At B you are getting saturated steam.

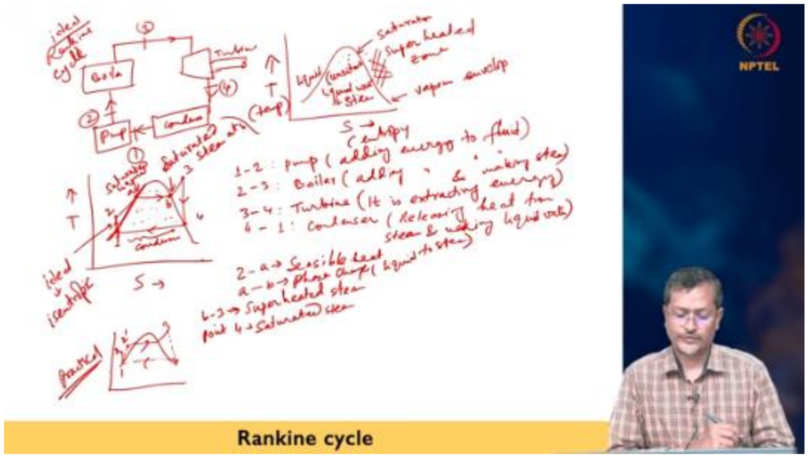
Let us say water, 1 atmosphere pressure, 100 degree centigrade temperature, you form steam. Now, you increase temperature further, do not change the pressure. In that case, what will happen? Your temperature increasing and your entropy also increasing, so you are reaching to 0.3. That is called superheated steam.

Now, if you want to reduce temperature, you want to make liquid, so temperature will go down, down, down to, it will come to B, then again it will start forming liquid droplets. 3 to 4, 3 to 4 actually turbine work. inside turbine you cannot give liquid. liquid will have some difficulty. turbine will be handling only steam.

that is why you have to give superheated steam to turbine and after turbine exiting it can reach to 0.4. 0.4 saturated liquid or saturated steam you can say. four to one four to one phase change will be occurring so this is condenser work four to one i have written condenser so this is condenser okay so only condenser is giving only phase change this is because this is ideal cycle i am saying that is why all the points are lying for example point four is lying on the saturation curve But practically 0.4 may be inside or outside. B also, not B, B is not having any value.

A, this 1, 0.1, pump entry, pump entry also can be maybe outside the curve, saturation curve. 0.2 also can be differing because of non-isentropic condition, if it is practical. this is practical. practical cycle will be like this, then it will be going like this, it will go, it will go, then it will be giving less amount of energy. It will give energy, less amount of energy, so 1, 2, 2, 3, 4, 1.

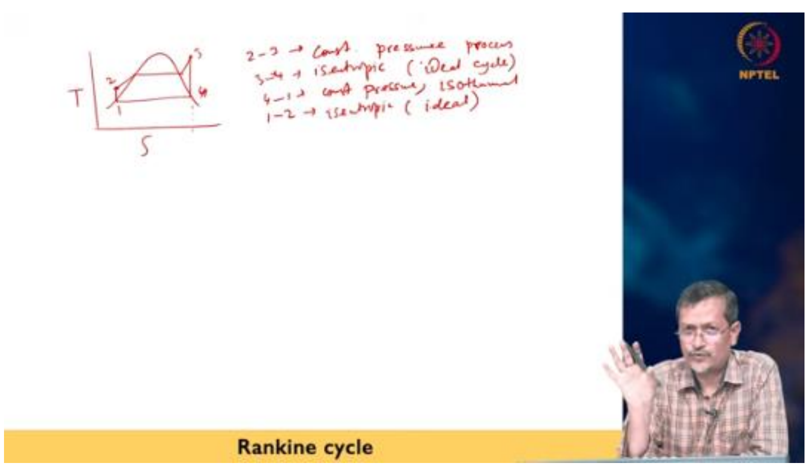
this way it will work. whenever you are drawing figure, you should draw the arrow direction also, you should write details of everything. I will draw the TS diagram again. TS, some more things are there to explain here. I said like it is ideal cycle.



everything will be on an ideal situation. 1, 2, 3, 4. inside boiler 0.223 happening. 223 actually constant pressure process. 2 to 3 it is inside boiler and pressure is not changing it will be occurring in with isobaric condition constant pressure or isobaric condition pressure process and 3 to 4 pressure is getting changed. So, 3 to 4 in for ideal cycle

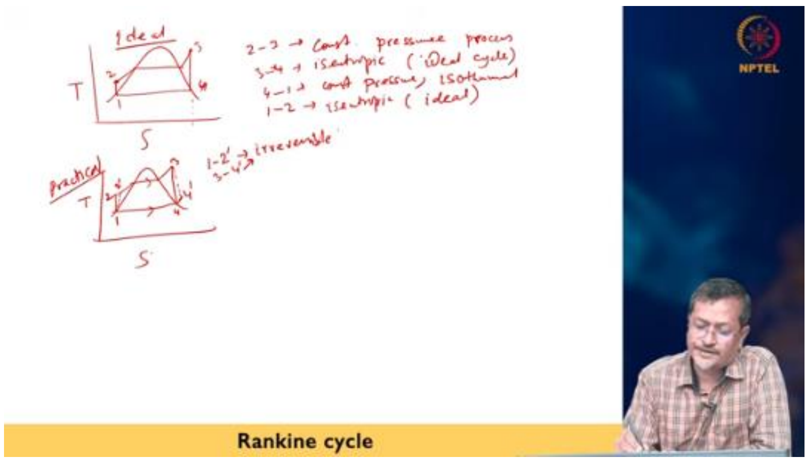
my entropy not changing so it is you can see completely vertical so isentropic isentropic ideal for ideal cycle even to four to one it is again constant pressure process four to one constant pressure again isothermal also same temperature will be maintained right Because phase change occurring, during phase change, temperature will not change. this is isothermal process or temperature not changing. And 1 to 2, again isentropic, I am saying ideal conditions. ideal.

Practically, things will be different. 1 to 2 and 3 to 4 special turbine and pump work, it will be different. this is an ideal cycle. And practical TS, practical will be like this, envelope, I have ideal cycle first you draw, then ideal cycle will be like this, 1, 2 dash, 3, 4 dash. So, you are giving more energy, you are getting less amount of energy.



So, 2 dash 1 to 2 dash isentropic, non-isentropic, so it is irreversible process. Irreversible process, whenever we say, actually we put some dotted line, that means it is not reversible. energy will be lost, entropy will be generated. entropy gone up, you can see this 1 to 2 dash line length is longer. that means you are giving more energy to pump.

3 to 4, you can see you are getting less energy from the turbine. these are both irreversible processes, 3 to 4 dashs. This is a practical thing. But ideally, for simplicity, we assume that there is no entropy generation. For the initial calculation, we will go through an ideal cycle.



After that, later stage, we will go through this practical cycle, which are the different losses we will try to calculate.