Steam Power Engineering
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Lecture-08
Examples of Reheat Rankine Cycle

Welcome to the class, now we are going to see some examples on Rankine cycle with reheat or the example which are related with steam power plant with reheating arrangement.

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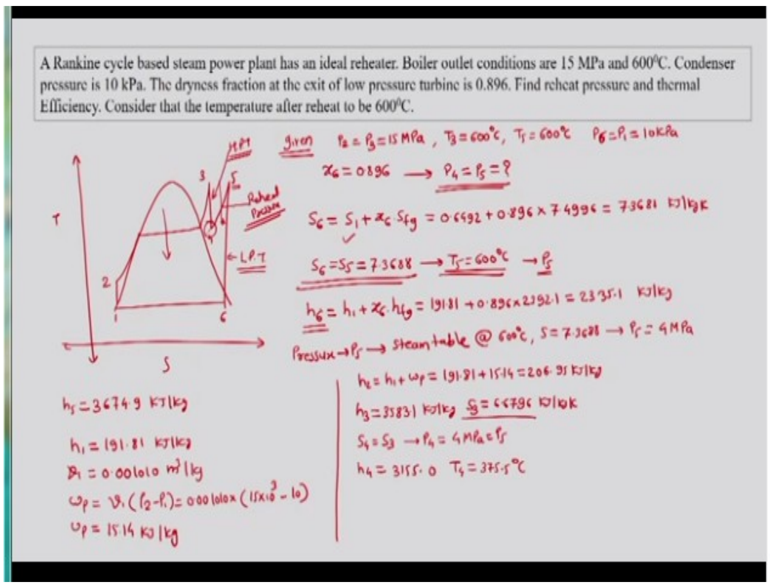

So the first example reheat that the Rankine saying cycle based steam power plant has an ideal reheater, boiler outlet conditions are 15 MPa and 600°C condenser pressure is 10 kilo pascal. The moisture content at the exit of the low pressure turbine is 0.896 that means dryness fraction is given as 0.896. The example reheat is that Rankine cycle based steam power plant has an ideal reheater, boiler outlet conditions are 15 MPa and 600°C, condenser pressure is 10 kilo pascal.

The dryness fraction at the exit of low pressure turbine is 0.896, find reheater reheat pressure and thermal efficiency consider temperature after reheating or after the reheat is to be 600°C. So let us draw for that reheat cycle and then name all the corners, this is, so this is how the Rankine cycle with reheat is. Let us correlate it with given things, so in the given things we are told that $P_2 = P_3 = 15\ MPa$, T_3 is said as $600°C$ we are also told that T_5 is also 600°C. We are told that

$P_6 = P_1 = 10\,kPa$ and we have x_6 as 0.896. We are supposed to find out what is P_4, what is P_5 so this is what first thing we have to find out.

So for that we can first find out entropy S_6 so we know a S_6 can be found out by saying that it is $S_1 + x_6 S_{fg}$, S_1 can be found out at 10 kPa liquid saturation entropy which is $0.6492 + 0.896\,S_{fg}$ which is $S_{fg} = ¿7.4996$. So this gives us S_6 as 7.3688 $kJkg.K$, so this is the entropy at exit of the low pressure turbine, we know this is low pressure turbine and this is high pressure turbine having said this we can say that $S_6 = S_5$ which is 7.3688.

Now we also know T_5 = 600°C, so basically here we can go into this steam table in the superheated part of the steam table and see 600°C corresponding to different pressures and find out the pressure and corresponding to temperature 600°C which would have entropy 7.3688. So that pressure becomes the basically the pressure P_5, so we can do that similarly knowing this we can find out $h_6, h_6 = h_1 + x_6 h_{fg}$, so it is $191.81 + 0.896(2392.1)$ and we get $h_6 = 2335.1\,kJ/kg$.

So we can get from this known quantities, however we would go as suggested for in the steam table. So pressure P_5 can be found out from steam table at 600°C and S_5 as 7.3688. So, we get this with P_5 and this P_5 remains as 4 MPa. So here at the same state we can find in h_5 which terms out to be 3674.9 kJ/kg. So now we know P_5 we know everything at state 5 enthalpy also is known to us.

So now we will proceed with other things, so for that we can know first h_1 and h_1 for us is here 191.81 kJ/kg. And then we should know v_1 this is $0.001010\,m^3/kg$, so we can find out pump work as $v_1(P_2 - P_1)$ so $0.001010 \times (15 \times 10^3 - 10)$. So this gives in kJ/kg, so pump work in kJ/kg terms out to be 15.14 kJ/kg.

Now we can find out $h_2 = h_1 + W_P$, so we have 191.81 + 15.14 and then this terms out to be 206.95 kJ/kg. Now we know h_2 we can find out h_3 and h_3 we can find out from steam table and we go to the 15 MPa superheated condition find out the enthalpy and entropy corresponding to 600°C. So h_3 at this state will be 3583.1 kJ/kg, S_3 at the same location 6.6796 kJ/kg K.

So we can now find out this state 4, here we should also remember $S_4 = S_3$ but we know $P_4 = 4 MPa$which is basicallyP_5. So again we will go to the steam table, we will look into the 4 MPa case and find out what is the temperature at which if we can get the entropy as S_3 ok. So it terms out to that we can find out the temperature and this temperature can be the saturation temperature the 0.4 can be inside the dome or 0.4 can be outside the dome.

If 0.4 is inside the dome and we would have to find out the dryness fraction for 0.4 if it is outside the dome then we know that it will have dryness fraction 1. So here we will get h_4 = 3155.0 since T_4 turns out to be 375.5°C. So we can go ahead. And do the next calculations which are for $Q_{¿}$ equal to.

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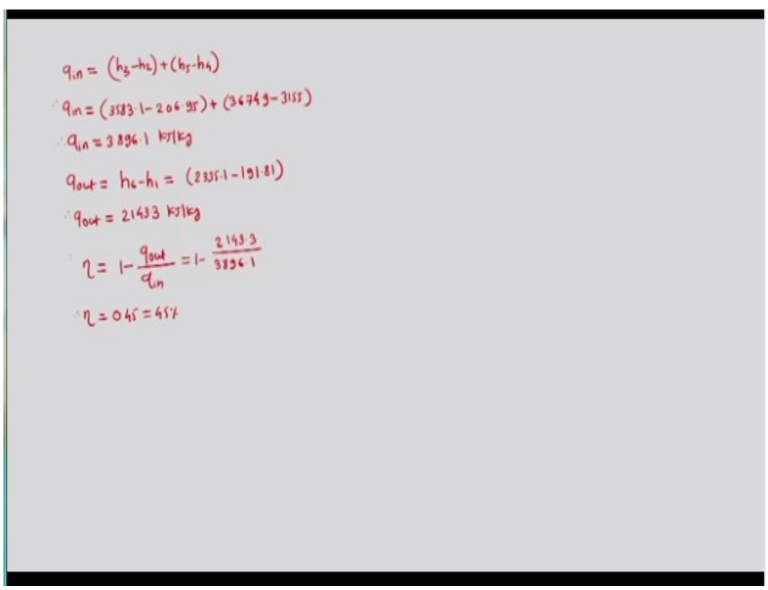

We have to remember that we are adding heat in 2 places; we are adding heat here in the boiler and in the reheater. So it is h_1, so it is basically $(h¿¿3 - h_2) + (h_5 - h_4).¿$

So $q_{¿}$= (3583.1 – 206.95) + (3674.9 – 3155) and we get $q_{¿}$ as 3896.1 kJ/kg similarly we can find q_{out} and $q_{out} = h_6 - h_1 = 2335.1 - 191.81$. So we have q_{out}= 2143.3 kJ/kg, so cycle efficiency is equal to$\eta = 1 - \frac{q_{out}}{q_{¿}}$. So which is $1 - \frac{2143.3}{3896}$, so cycle efficiency become on 0.45 which is 45%, so this is how we would have to solve the example. Here we have to keep 1 point in mind that in the example in some cases we would not be given as in this example the pressure which is the reheat pressure and we have to find out reheat pressure from the entropy equal condition at $S_6 = S_5$ and $S_4 = S_3$.

So using this conditions we have find out location of 0.4 by one match which is $S_6 = S_5$ we can identify the pressure and by making other match which is $S_3 = S_4$we will get it is temperature known or maybe along with temperature we can also know whether the point is inside the dome or outside the dome.

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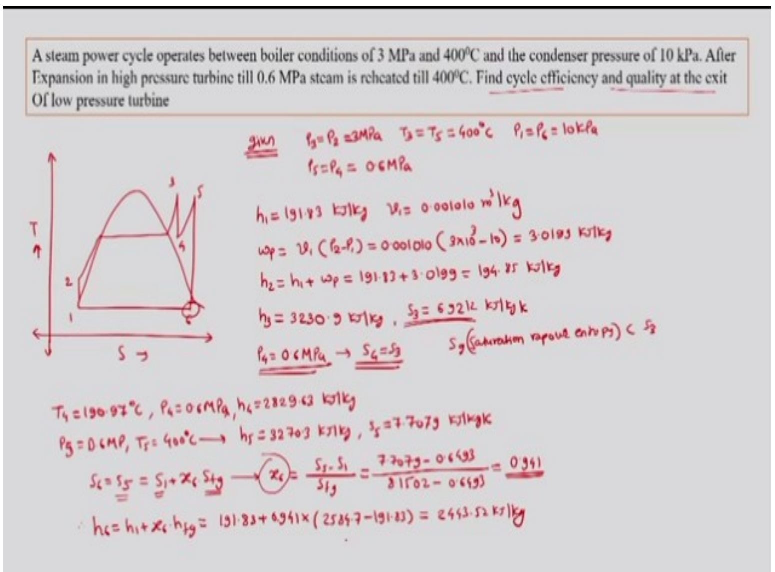

We will go ahead with the next example it reads that steam power plant operates between boiler conditions of 3 MPa and 400°C and condenser pressure of 10 kPa ok.

After expansion in high pressure turbine till 0.6 MPa, steam is reheated till 400°C point out cycle efficiency and quality at the exit of low pressure turbine. In this example we are given with reheat pressure, so we do not have to find it out. But what is not known to us is the dryness fraction at the exit of the low pressure turbine. So this is 1, 2, 3, 4, 5, 6 so given is $P_3 = P_2 = 3\,MPa$, then $T_3 = T_5 = 400\,°C, P_1 = P_6 = 10\,kPa$.

And then $P_5 = P_4 = 0.6\,MPa$ then here we will go ahead with our classical known things first h_1 can be known corresponding to 10 kPa which is 191.83 kJ/kg v_1 is known as 001010 m^3/kg and then we can find out pump work which is $v_1(P_2-P_1)$ which is $0.001010(3\,kPa-10\,Pa)$ and the unit will be in kJ/kg which is 3.0199 kJ/kg.

So we know $h_2=h_1+W_P=191.83+3.0199$ and then we get h_2 as 194.85 kJ/kg. So we can find out still h_3 which is corresponding to 400°C, 3 MPa. We have to go into the superheated part of the steam table and find out h_3 and h_3 is 3230.9 kJ/kg immediately we will note down S_3 and S_3= 6.9212 kJ/kgK. Now we know that P_4 = 0.6 MPa and we also know that $S_4=S_3$, now we know S_3 so we have to go into this steam table first we have to see what is the saturation entropy of vapor at 0.6 MPa.

And that we have to compare with 6.9212, if 6.9212 is more than the saturation entropy of vapor then we have to go into the superheated part and match the pressure and temperature rather for 0.6 MPa we have to find out the temperature which would give the entropy. This if we find out that saturation enthalpy saturation entropy for 4 is or saturation entropy for 0.6 MPa is greater than S_4 in we find out x_4 which is dryness fraction at 4 ok. Since from that we can basically equate it is entropy with S_3.

So in the present case we will have basically S_g which is saturation vapor entropy is less than S_3. So we have to find out in super heated part and we get T_4 = 190.97°C seems we know P_4 = 0.6 MPa and then in that location we can find out h_4 and h_4 turns out to be 2829.63 kJ/kg. So now we can go in P_4basically P_5 as 0.6 MPa and T_5 as 400°C and find out h_5 and $h_5$gives us the value 3270.3 kJ/kg.

But at the same moment we will note down S_5 and S_5 is 7.7079 kJ/kgK. So now we can find out what is the state at 6 since we know $S_6=S_5$ and then which is equal to $S_1+x_6S_{fg}$. We have already wrote down S_1 for the 10 kPa case we would also know S_{fg} at 10 kPa. And then we already know S_5 which is 7.7079 and this gives us $x_6=\frac{(S¿¿5-S_1)}{Sfg}¿$, so it is $\frac{7.7079-0.6493}{S_{fg}}$is basically $S_g-S_f=S_{fg}=8.1502-0.6493$.

This gives us x_6 as 0.941, this is the dryness fraction at state 6. So we can find out h_6 and so by saying it is $h_1 + x_6 h_{fg}$ which is $191.83 + 0.941(h_{fg})$ and this $h_{fg} = h_f - h_g$ which is 25 84.7 – 191.83 and this gives us value as 24443.52 kJ/kg, using this numbers we can proceed and find out rest of the parameters.

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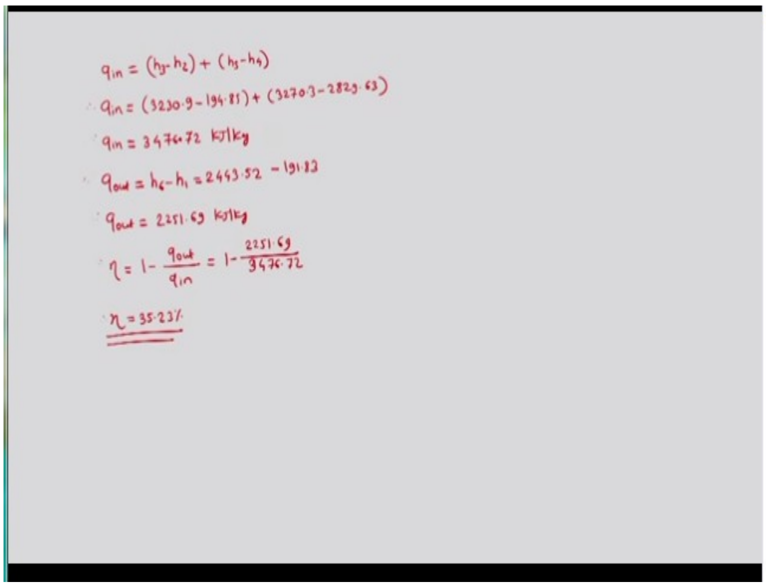

So we can find out $q_{¿}$ again there is heat addition in 2 places one is $h_3 - h_2$ into boiler and $h_5 - h_4$ in the reheater. So $q_{¿} = ¿$(3230.9 – 194.85)+$¿$3270.3 – 2829.63), so this is h_4 so from that we can get $q_{¿}$ as 3476.72 kJ/kg. Similarly we can find out $q_{out}$and $q_{out} = h_6 - h_1$ so it is 2443.52 – 191.83.

So we get q_{out}= 2251.69 kJ/kg, so we can find out efficiency as$\eta = 1 - \frac{Q_{out}}{Qin}$, so it is $¿ 1 - \frac{2251.69}{3476.72}$ and we get efficiency as 35.23%.

So in this example we will suppose to find out 2 things 1 is cycle efficiency and quality at the exist. Here the quotient quality refers to finding out dryness fraction at the exit of the low pressure turbine which we found out ok. So this is how we have to work with the example of reheater where either we would be given with the reheat pressure or we have to we have to find out the conditions at the exist of the turbine or we might be given conditions at the exit of the turbine.

And in we would have find out the reheat condition, so this the way we would solve the examples on reheater, thank you.