Concepts of Thermodynamics
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Lecture - 52
Supplementary Lecture: Problem Solving with the Aid of a Computer

Hello and welcome to the session in which we will consider the analysis of a turbine and see how we can find out the various states and how to address the performance of a turbine.

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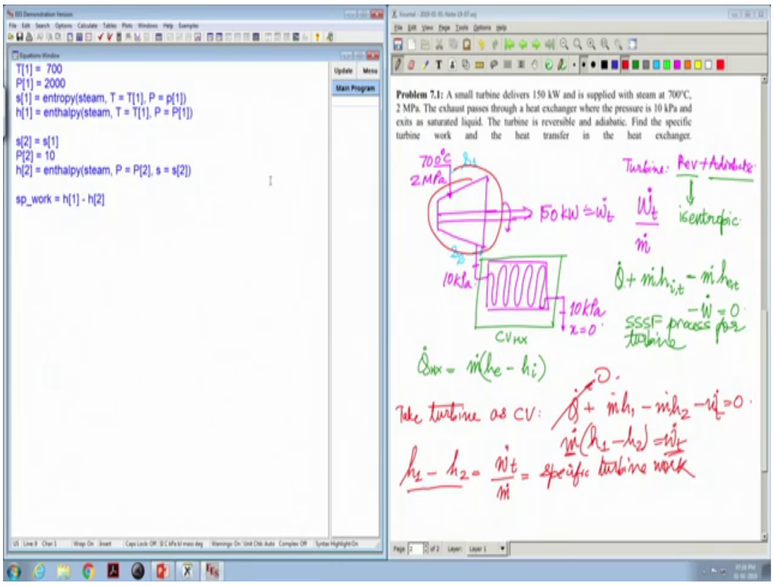

So, we are given that we have a small turbine which delivers 150 kilowatt of power. So, let me first draw the turbine. So, the power output work done by the system is 150 kilo watt this is W dot, turbine. It is supplied with steam at 700 degree Celsius and 2 mega Pascal, the exhaust passes through a heat exchanger where the pressure is 10 kilo Pascal and it exists as a saturated liquid.

This is the information that we have. So, the thing about heat exchangers is ideally the pressure drop is quite negligible as a result the inlet and the exit of the heat exchanger are both held at 10 kilo Pascal. So, it is given that the turbine is reversible and adiabatic. Find the specific turbine work and the heat transfer in the heat exchanger. So, the specific turbine work is equal to this divided by the mass flux and the heat transfer in the heat exchanger is simply found out by writing down the first law for this particular control volume CV HX is the control volume of the heat exchanger.

So, we have Q; Q dot plus m dot h i total plus m dot rather minus m dot h e total minus w dot is equal to 0, at steady state steady flow process ok. And so because in a heat exchanger there is no work done, we have Q dot HX is equal to m dot h e minus h i and if a turbine is reversible and adiabatic, what does it imply? It implies as you might have done in theory class that the turbine is also isentropic. So, if it is isentropic the entropy at this point so let me call this as s 1, if I call this as s 2, s 1 is equal to s 2.

So, let me quickly write down the values I have T 1 is equal to 700 degree Celsius, P 1 is equal to 2000 kilo Pascal, s 1 is equal to entropy a steam, T equal to T 1 and P equal to p 1. Similarly the enthalpy we may need it require a later on ok. At state 2 because the turbine is reversible and adiabatic we have s 2 is equal to s 1 and we have been given that the pressure in point 2 is 10 kilo Pascal.

So, h 2 is the enthalpy of steam, T equal to rather this should be P equal to P 2 and s equal to s 2. See in this particular problem we have made use of the fact that the pressure and the specific entropy are two independent quantities.

So, with the help of that we are able to find h 2 and so if I write down, if I take this as a control volume if I take the turbine as the control volume. So, for an ideal turbine there is no heat exchange from the turbine. So, Q dot plus m dot h 1 minus m dot h 2 minus w dot is equal to 0, this is 0. So, m dot h 1 minus h 2 is equal to w dot and w dot. So, let me write down let me divide everything by m dot. So, h 1 minus h 2 is equal to w dot turbine divided by m dot this is nothing, but the specific work output of the turbine. So, h 1 minus h 2, we have already found out what h 1 and h 2 are; h 1 minus h 2 there we are this one this.

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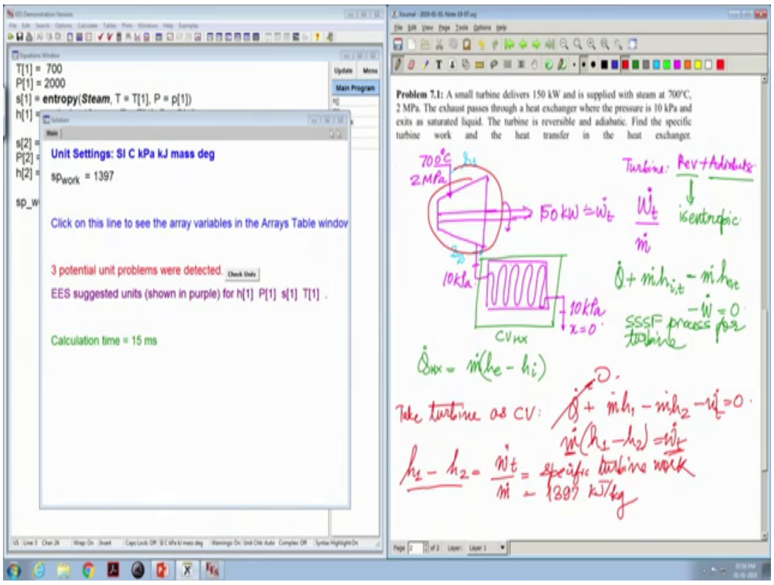

So, specific work is equal to 1397 kilo Joule per kg. Let us find out the heat transfer in the heat exchanger ok. As a matter of fact we need to find out the mass flux.

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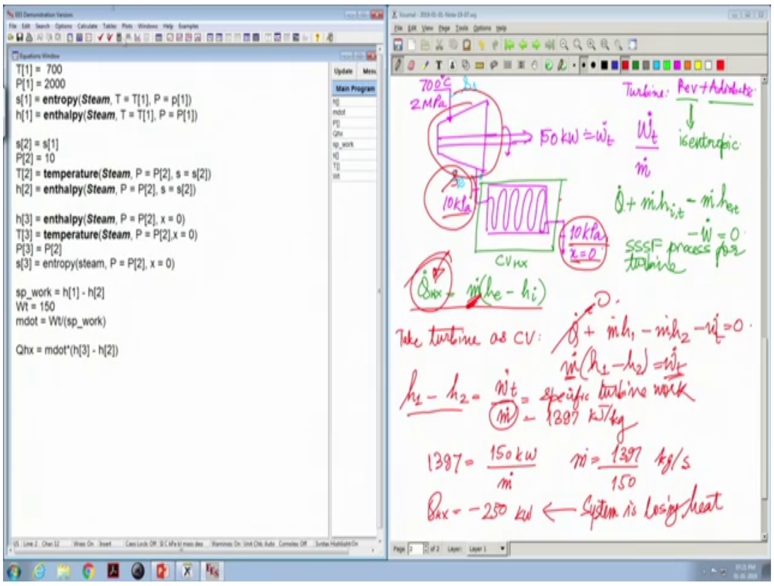

See, we know what this state is because we know the entropy and the pressure. Similarly we know what this particular state is because you know the pressure and the quality. What is not known is the mass flux? The mass flux is not known I cannot find out the heat transfer from the heat exchanger. So fine, 1397 is essentially 150 kilowatt by the mass flux. And thus the mass flux is equal to 1397 divided by 150, this is in kg per second.

So, then let me write down ok. So, this is what we have and then the heat transfer from the heat exchanger is essentially the mass flux multiplied by essentially h 3 minus h 2. Where h 3 is the enthalpy, steam at P equal to P 2 x equal to 0.

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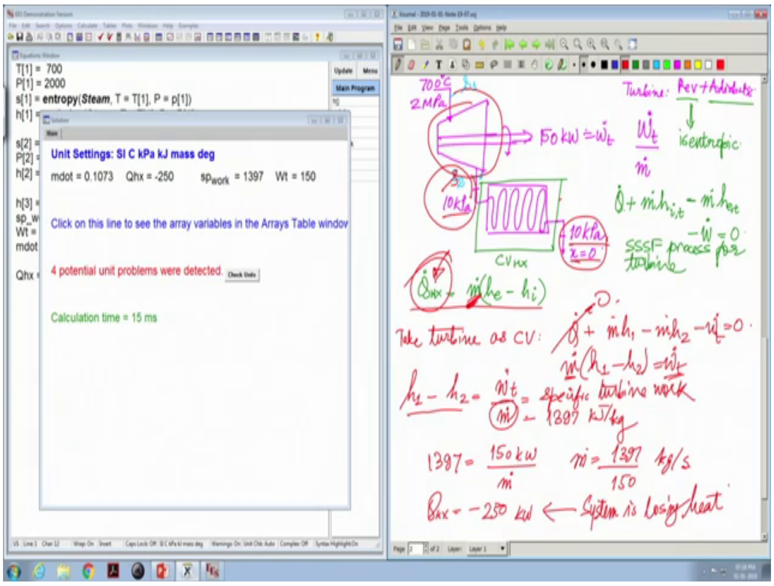

So, the heat transfer from the heat exchanger is minus 250 kilowatt, it is a huge amount of heat transfer by the way. And so the heat as per the sign convention here, the heat transferred to the system is positive and because we have a negative ones it means the system or the control volume this green control volume is losing heat. Essentially the heat exchanger is losing heat it is losing heat to take steam from state 2 to state 1. In fact, just for visualization.

Let us go ahead and plot all the points now let me fetch the temperature, I need the values of P. So, let me do that in fact, P is given as 10 kb oh you know. So, P 3 is simply P 2. So, let me try to go and plot probability plot steam (Refer Time: 11:06).

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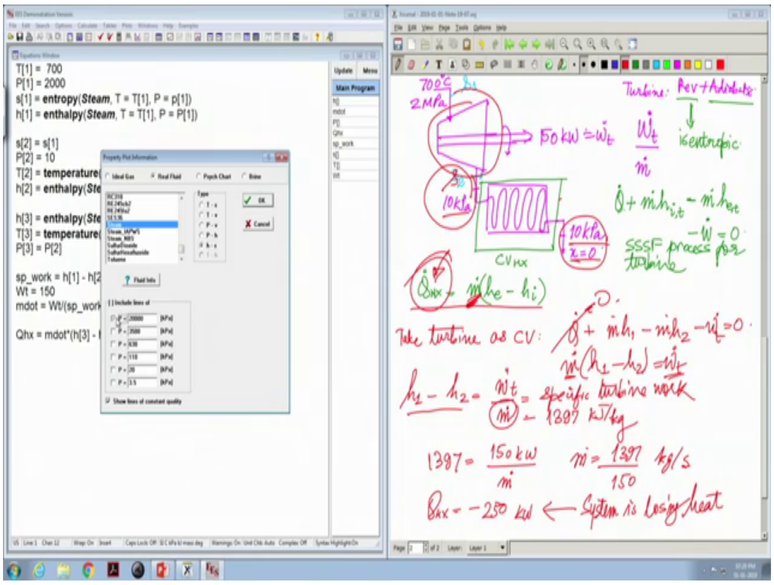

So, this is 2 mega Pascal and we need another plot at 10 kilo Pascal.

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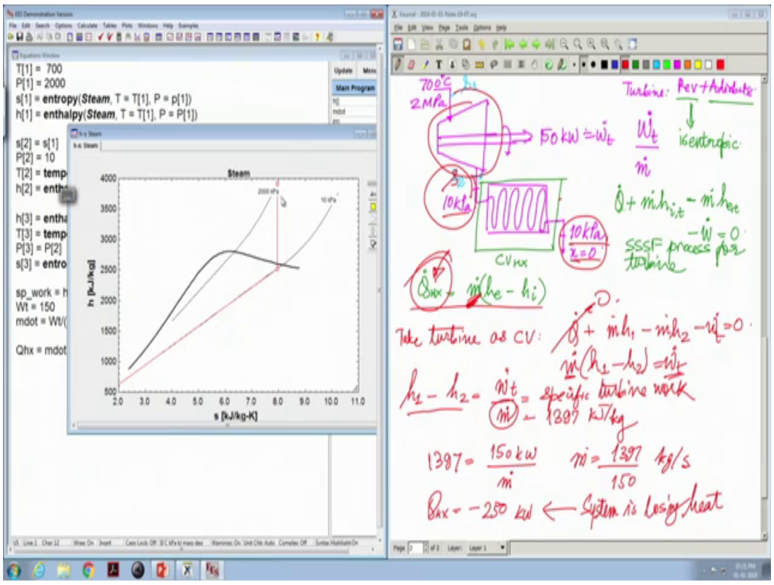

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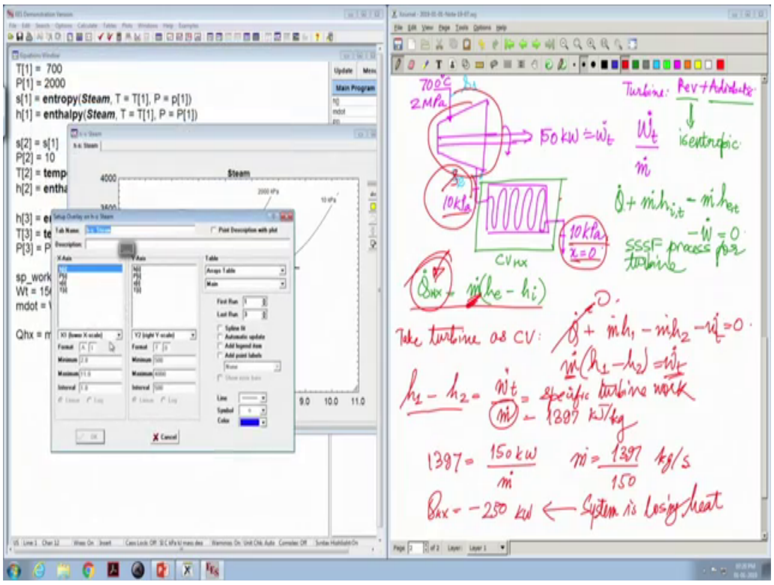

On the x axis we have the entropy, on the y axis we have the enthalpy. I am missing value so let me just quickly fetch s 3. This is incorrect because this should be x equal to 0 (Refer Time: 12:20). You have to plot over lay plot (Refer Time: 12:27) ok.

So, we had something which is lying on this point ok, something over here and then it went from this point to this point. And we reached inside the dome and see this is the 10 kilo Pascal iso bar and inside the heat exchanger because you are losing heat you go from this particular value of entropy and you decrease.

You are losing this much amount of heat. So, essentially the diagram looks like this. So, as a small exercise I asked you to find out the total entropy generation during the process. And then you have to assume that the ambient is at some 20 degree Celsius or 25 degree Celsius depending on where you are. And then see if that checks out with the second law of thermodynamics it should be always positive or rather non negative.

So, with this we conclude this particular problem, it was a problem in which we had two control volumes it was a very easy problem, but it highlighted a simple concept that for a reversible adiabatic turbine, the process also isentropic.

So, with this we conclude this session and I will be back next time with another problem.

Thanks.