Cooling Technology: Why and How utilized in Food Processing and allied Industries

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Module No 07

Lecture 32
Dry Compression

Good morning, my dear friends and students. Hopefully you have gone across in the previous class why Carnot cycle being the most efficient cycle cannot be commercially used, what are the difficulties which we have said right. And hopefully you have understood we have repeatedly said why it is not able to use in the commercials level right. And there one thing came out that it was because one of the reasons were that it was because of the wet compression right and because of the wet compression the feasibility of using Carnot cycle became very difficult or is not possible. Now we came from there that yes if there is a dry compression right, if there is a dry compression that could be one of the solutions for the that could be one of the solutions for the wet compression or replacement of wet compression right. So, one of the way by which you can achieve this wet compression replacement is through dry compression in the Carnot refrigeration cycle.

So, instead of wet we are now doing dry compression right and dry compression also we said that means, no liquid only the vapour or gas is to be compressed right. Then that we said that liquid droplets heating like bullet and the plunger or the pistons which are having sheets though sheet materials are not getting damaged right. So, for that what we need? We need one isentropic compression and one isothermal compression and this is shown in this picture right. Here we are doing one isentropic compression that is this one isentropic compression and one isothermal this one is from there and then as we did from this isothermal expansion that was is also done right.

So, two isentropic compression what was in the original Carnot cycle that now if we are replacing with one isentropic compression and one isothermal expansion that you are doing right. So, you see that pressures here the pressure is p 1 that is what p e right and here it is p i intermediate and here it is p c. So, p c is the highest and p i is the intermediate and p e is the lowest pressure. So, isentropic compression and then isothermal compression these two will help to reach the one which we had seen in the T-S diagram as this was there right. So, you went up to this then this then this and then this.

Now instead of this liquid vapour mixture we are avoiding we are coming to the saturation line. So, from there we are isentropically compressing it to the point 2 and for then from the point 2 to point 3 we are compressing isothermally right then reaching the point 3 which is here. So, from 2 to 3 was here now that we have replaced ok. So, this is one good suggestion for replacement of the wet compression with the dry compression. For that as we said that we need two compressors and those two compressors are shown here as this one right.

So, that is doing W 1 to 2 that is isentropic compression and W 2 to 3 is again isothermal compression which we have done a replacement of wet compression with dry compression, but we need one and two compressors right. For the same work we need two compressors that is one and two right ok. After that the same thing happening from 3 to 4 this part which was also there in our Carnot system that 3 to 4 this was isothermal expansion and then 4 to 5 that was isentropic compression right. So, two compressions is isentropic and two isothermal expansions were there for the Carnot system. We are now doing one isentropic compression and one isothermal compression and in that we are using two compressors right and other all remaining the same as it was in the Carnot system right they are remaining same.

So, this is a dry compression and that is called Carnot refrigeration system with dry compression. So, what we can now say is that with dry compression we have to have two compressors. Obviously if some work at your home is being done by one person do you like to have one more person to do the same work perhaps not. So, here also that difficulty is arising. So, as we are seeing in that figure this just previous figure which we have shown the Carnot refrigeration system with dry compression consists of one isentropic compression and that is point 1 to 2 or state point 1 to 2 from evaporator pressure Pe to the to an intermediate pressure Pi and temperature remaining Tc followed by an isothermal compression process that is from point 2 to point 3 that is state point 2 to state point 3 from the intermediate pressure Pi to the condenser pressure Pc. Though with this modification the problem of wet compression is avoided, but still this modified system is not practical because of the difficulty in achieving number one true isothermal compression and using high speed compressors and the other one is use of two compressors in place of one is not again economically justifiable right. So that the fundamental thing you see when you are compressing right when you are compressing a gas between this with a piston that what is happening this piston is coming and compressing this right. So, what is happening the pressure here was say Pe and here the pressure say Pi according to our this modified dry compressor. So what is happening the pressure is increasing obviously, Pi is greater than Pe.

So pressure is increasing the moment pressure is increasing and obviously, from the piston you see the volume is also decreasing from whatever volume here it was the other volume at Pi at this point. It is next to impossible from this P v is equal to RT that relation keeping change both P and V keeping T constant right. So keeping T constant means it is becoming isothermal. So isothermal compression is practically very very difficult. So we cannot use the isothermal compression besides using two compressors is also economically not justifiable.

Then what happens? Then from this discussion we can say that it is clear that from practical considerations the Carnot refrigeration system need to be modified and not only dry compression with a single compressor that is required. If the isothermal heat rejection process if the isothermal heat rejection process is replaced by isobaric heat rejection process. So isobaric heat rejection means as you know it is P is constant right that is the isobaric. So under constant pressure that isothermal heat rejection process is replaced with isobaric heat rejection process. If this can be done one another change that is the isentropic expansion process that was isentropic expansion process was if you remember in this was isentropic expansion right from point 3 to point 4. So this was isentropic expansion process and that can be replaced by an isenthalpic throttling process. So that means enthalpy H is constant. So if these two are done or replaced achievable then a refrigeration system which incorporates these two changes is known as Evans-Perkins or reverse Rankine cycle. So what did you do? We have replaced one isothermal expansion with isobaric expansion or heat rejection and the other one is that isentropic expansion was also replaced by isenthalpic throttling process and this is known as Evans-Perkins or reverse Rankine cycle. This is the theoretical cycle on which the actual vapour compression refrigeration system is based on right.

So what we can do? We have seen it that one isobaric and one isenthalpic these two process we have to incorporate for modification of the Carnot right. Now if we look at the Carnot efficiency in the earlier class we had shown you also that Carnot efficiency if we take a problem a Carnot heat engine operating between a high temperature source at 900 Kelvin and rejected heat to a low temperature reservoir at 300 Kelvin determine the thermal efficiency of the engine number 1. Now if the temperature of the high temperature source is decreased incrementally how is the thermal efficiency changes with temperature? This problem part we have done earlier right. Now if we look at this problem that we have found out yeeta thermal this was 66.7 percent this we have done earlier also.

Now if we fix T L at 300 Kelvin and lower T H then what will happen? Yeeta thermal that becomes 1 minus 300 by T H right. So if T H is increased then this ratio is decreased that means 1 minus this ratio is increased that means yeeta thermal is increased right this is true and we can we can show it from here that yeeta thermal this is T H or T L depending on which one you are taking right. So, this is T L. So, what we said that with a fixed T L that is here with a fixed T L. So here we take the T H or thermal efficiency that is here if we increase T H then this 300 by T H that fraction reduces.

So, 1 minus that fraction is increased that means yeeta thermal is getting increased right. So, the higher the temperature the higher is the quality of the energy and more work can be done right and if we have this was for fixed T L. Now if we do for fixed T H right if the T H is constant at 900 Kelvin and we increase T L right. So, if T L is increased then this ratio is decreasing then 1 minus this ratio that is increasing. So, yeeta thermal is also increasing right.

So, this is 900 and this say was 300 say now you made it to 600. So, this ratio when it was 300 it was 1 by 3 that is 0.3 when you made it 600 then it is 2 by 3 right it is 0.6. When you once again when you increased when you keeping 900 constant it was 300.

So, 300 by 900 that is one third that is 0.3. So, 1 minus 0.3 is 0.7 right whereas, when you made it 600.

So, 600 by 900 so that means 6 by 9 that means 2 by 3 2 by 3 is 0.6 that means 1 minus 0.6 is 0.4. So, it is decreasing right if for a fixed T H if you are increasing the T L value then 1 minus this is decreasing that means yeeta thermal is decreasing is it.

So, T H like that and this we have also said earlier right. Now, the question then comes that Carnot efficiency that if we summarize that similarly the higher the temperature of the low temperature sink the more difficult for a heat exchange engine to transfer heat into it. Thus lower thermal efficiency also which we have just shown right sorry which we have just shown and one is to increase the thermal efficiency of a gas power turbine one would like to increase the temperature of the combustion chamber. However, that sometimes conflict with other turbine requirements and example of it could be that the turbine blades cannot withstand high temperature gases. So, this leads to early fatigue of the blades.

Solution could be better material that can be found out or research can be done on that. So that it can replace them or innovative cooling that design can be incorporated right. So this is the second third one is work is in general more valuable compared to heat since work can since work can convert to heat almost 100 percent, but not the other way round right. Work can be converted almost to 100 percent to heat, but heat cannot be converted 100 percent to work or near to that. So, heat becomes useless when it is transferred to low temperature sources because the thermal efficiency will be very low according to T

H is equal to 1 minus T L over T H right that is the thermal efficiency.

So it says that when heat is transferred to a low temperature source this is very much useless because the thermal efficiency will be very low and according to the efficiency definition that yeeta thermal is equal to 1 minus T L over T h. So, this is why there is a little incentive to extract the massive thermal energy stored in the oceans and lakes. Yeah every you hope you have seen ocean and every second you have seen that waves are coming and heating right. So, the question comes why cannot use that wave energy. So, that is what it is that this is why there is a little incentive to extract the massive thermal energy stored in the oceans or lakes right.

So, with this our time is up today. So, we have concluded the Carnot efficiency and also shown the effect of the high that is high temperature or low temperature on the Carnot efficiency right. We have also introduced dry compression we also have said time is very limited. So, let us tell it in the next class. Thank you very much.

Carnot Efficiency

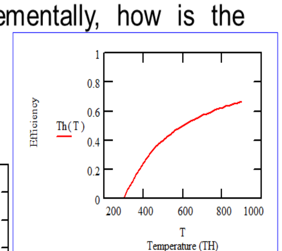
A Carnot heat engine operating between a high-temperature source at 900 K and reject heat to a low-temperature reservoir at 300 K. (a) Determine the thermal efficiency of the engine. (b) If the temperature of the high-temperature source is decreased incrementally, how is the thermal efficiency changes with the temperature.

$$\eta_{th} = 1 - \frac{T_L}{T_H} = 1 - \frac{300}{900} = 0.667 = 66.7\%$$

Fixed $T_L = 300(K)$ and lowering T_H

$$\eta_{th}(T_H) = 1 - \frac{300}{T_H}$$

The higher the temperature, the higher the "quality" of the energy: More work can be done



Fixed $T_H = 900(K)$ and increasing T_L

$$\eta_{th}(T_H) = 1 - \frac{T_L}{900}$$