Steam Power Engineering
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Lecture - 32
Psychrometry

Welcome to the class. We had actually started discussion about psychrometry where the major focus was towards the calculation of properties for humid air. There is a tool which is very much helpful for psychrometry and it is called as psychrometric chart. Today's topic of discussion is psychrometric processes and psychrometric chart.

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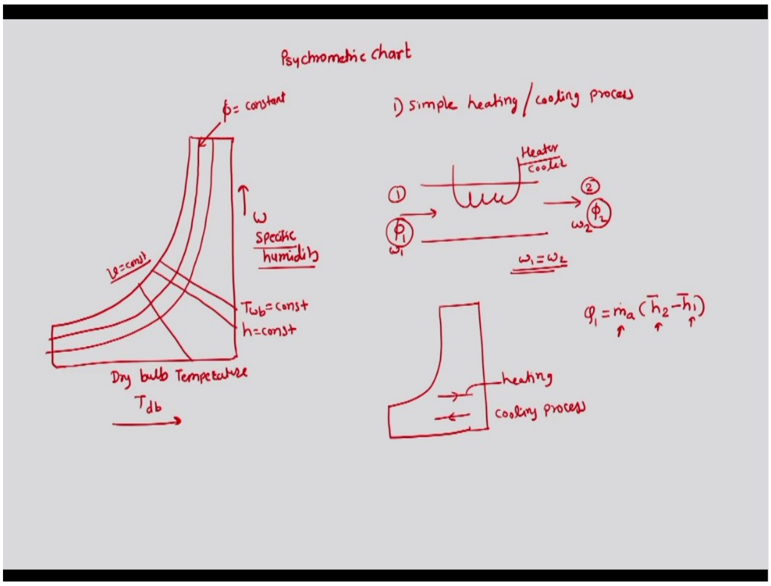

So, let us see, so first let us see psychrometric chart. This is basically a chart which has 1 y-axis, 1 x-axis where this y-axis is the specific humidity and x-axis is dry bulb temperature, x-axis for this chart is dry bulb temperature and so this is T dry bulb. So, this is specific humidity, this is dry bulb temperature and then there are like our $P-V$ chart, like our $T-S$ chart, this is also a chart with of ω versus T_b but this is little unusual and here we can show different lines.

So, first line what we can show is this and such lines are constant phi lines in which phi is constant, relative humidity is constant. Then, we can as well draw 2 lines, one is this kind of line which is having T wet bulb constant. So, this is a constant wet bulb line and constant wet bulb line can also be treated as constant enthalpy line since they are all most parallel with each other, so this is h constant.

And then there is one more line which is specific volume constant. So, these are the different lines on this psychrometric chart. Now, what we are going to see are the different processes on the psychrometric chart. We know suppose we take $T-S$ diagram, then this line shows isothermal process, this line shows isentropic process and then there would be one more line which is suppose like this which is constant pressure process.

So, as what we show on $T-S$ diagram similarly we can show different processes in the psychrometric chart. So, psychrometric chart let us talk about some processes. First process we are talking about is simple heating or cooling process. Suppose there is a duct and in which this is a heater so if you need air is coming at state 1 and humid air is leaving at state 2 and suppose this is a heater, so in this case air will get heated.

But we have to remember one point that this air will have some omega 1 and some $omega\,2$ at the outlet and some ϕ_1 and some ϕ_2 at the outlet. Here, ω_1 remains equal to ω_2 since specific humidity is not going to change in this process. This is as well true for the simple cooling process also where this will be a cooler or cooling circuit. However, as we had already seen that heating would increase the temperature and hence the bearable capacity of the air for the vapour.

So, this will change the relative humidity at the outlet with respect to inlet. So, this process of simple heating or cooling can be demonstrated like this on the chart by this, suppose this is heating process and then this is cooling process. So, by this we have to draw horizontal line for a given dry bulb temperature, we have to draw horizontal for a given dry bulb temperature we have to draw horizontal line at constant ω.

And then accordingly, we can get final state on that horizontal line for the simple heating or cooling process. Now, what is the amount of heat added or heat rejected? This Q is amount of heat interaction that is equal to $Q=\dot{m}_a(h_2-h_1)$ where we know that $\dot{m}_a$ is mass of air and $h_2 \wedge h_1$ are the enthalpies per unit dry air's mass at the outlet and at the inlet. Having said this we will see the next process which is called as heating and humidification.

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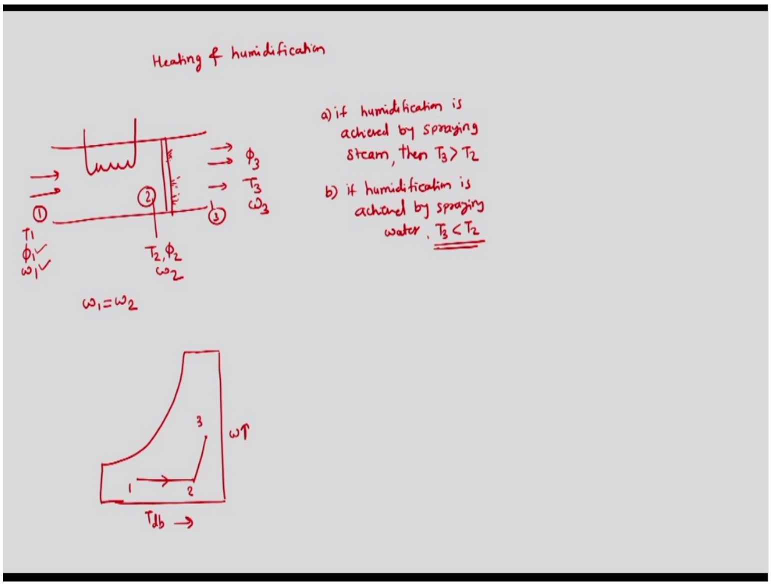

The process is heating and humidification. In this process, we can have a heater and this heater will first heat the air coming with certain dry bulb temperature, certain specific humidity, certain relative humidity, certain specific humidity. Then, there will be some injection of water or steam after station 2, station 3 and it comes out at state 3 where it will have ϕ_3, T_3 and ω_3 and at station 2, it will have T_2, ϕ_2 and ω_2.

We can understand the process 1 to 2 over here is simple heating process, so we have ω_1 ¿ ω_2 but after that we are adding liquid, water or steam in the process 2 to 3 for humidification, then $\omega_2 \neq \omega_3$. So, here this process can be shown on the chart where we will have 1 o 2 is heating and then 2 to 3 is humidification process where we are increasing the omega.

So, this is what we have to keep in mind. Here, we have to remember if humidification is achieved by spraying steam, then T_3 is greater than T_2. If humidification is achieved by spraying cold water or water, then T_3can be less than T_2. This is what we have to remember. So, temperature here at this moment this is state 3 we are saying that T_3 is greater than T_2 that means we are expecting the spraying of the steam is taken place in the process of humidification.

If we are spraying liquid water, then water will evaporate, it will take the latent heat from the air and in this case, air would reduce its temperature. So, T_3 might be lesser than T_2. Now, we can have next process which is cooling and dehumidification.

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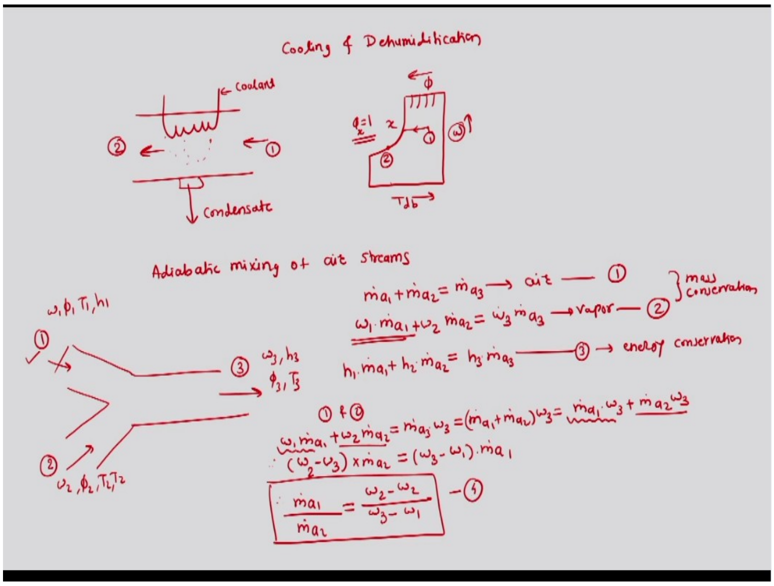

And this process can again be shown in schematic way where we will have some coolant passing in the circuit and then we have state 1, we have state 2 and then there will be condensate and that condensate will be taken out. So, in this process, we can see that if condensate is coming out, then this is dry bulb temperature, this is ω and then we first will have decrement of the temperature 1 to x in this coolant where phi is increasing in this direction.

And then what would happen is at x, we will reach $\phi=1$; ϕ at $x=1$. Then, condensation will start and then you will reach state 2 where we would have lower temperature than state 1 and then we would have higher relative humidity after the removal of the condensate where ω or specific humidity has decreased. So, this is dehumidification.

So, we have reduced the specific humidity and we have reduced the temperature. There is fourth process which is adiabatic mixing of air streams. Here, in this process, we can consider that there are 2 channels which are mixing and then forming one stream. So, this is 1, this is air at state 2, this is air at state 3. So, state 1 has its own ω_1, ϕ_1, T_1, h_1. This will have $\omega_2, \phi_2, h_2, T_2$ and then we will have ω_3, h_3, ϕ_3 and T_3.

Here, we can remember that $\dot{m}_{a_1} + \dot{m}_{a_2} = \dot{m}_{a_3}$ this is for air. Then, for water vapour we will have $\omega_1 \dot{m}_{a_1}$, this is specific humidity is mass of vapour per unit mass of dry air, so we have multiplied. So, this is mass of vapour in state 1 plus mass of vapour in state 2 is equal to mass of vapour in state 3. So, this is for vapour and will name it as equation 2, this as equation number 1 and both are mass conservation equations.

Now, we will write down energy conservation equation where we will have $h_1 \dot{m}_{a_1}$this is specific enthalpy which is enthalpy per unit mass of dry air plus $h_2 \dot{m}_{a_2}$ is equal to $h_3 \dot{m}\, a_3$. This is equation 3 and this is energy conservation. Let us take equation 1 and 2, so we can write down $\dot{m}_{a_1} + \omega_2\, \dot{m}\, a_2$gives us $\dot{m}\, a_3 \omega_3$ which is equal to $\dot{m}_{a_1} + \dot{m}_{a_2} \omega_3$ which is $\dot{m}_{a_1} \omega_3 + \dot{m}_{a_2} \omega_3$.

So, we have $(\omega_2 - \omega_3)\dot{m}_{a_2} = (\omega ¿¿ 3 - \omega_1)\dot{m}_{a_1} ¿$. So, we can write down $\frac{\dot{m}\, a_1}{\dot{m}\, a_2} = \frac{\omega_2 - \omega_3}{\omega_3 - \omega_1}$. This we will name it as equation number 4 and now we will go ahead and write down the energy equation.

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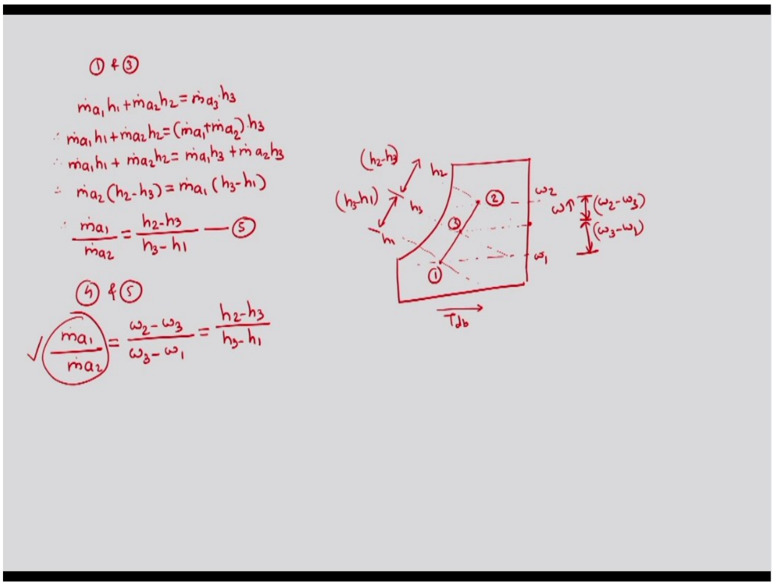

Again, consider 1 and 3 we can write down $\dot{m}_{a_1} h_1 + \dot{m}_{a_2} h_2 = \dot{m}_{a_3} h_3$. So, we have $\dot{m}_{a_1} h_1 + \dot{m}_{a_2} h_2\, gives\, us \left(\dot{m}_{a_1} + \dot{m}_{a_2}\right) h_3$. So, $\dot{m}_{a_1} h_1 + \dot{m}_{a_2} h_2 = \dot{m}_{a_1} h_3 + \dot{m}_{a_2} h_3$. So, we can have $\dot{m}_{a_2}(h_2 - h_3) = \dot{m}_{a_1}(h_3 - h_1)$ so we have $\frac{\dot{m}\, a_1}{\dot{m}\, a_2} = \frac{h_2 - h_3}{h_3 - h_1}$. So, this is equation number 5.

So, we can write from 4 and 5 as $\frac{\dot{m}_{a_1}}{\dot{m}_{a_2}} = \frac{\omega_2 - \omega_3}{\omega_3 - \omega_1}$ which is also equal to $\frac{h_2 - h_3}{h_3 - h_1}$. Now, this is very simple to identify states, state 3 if we know that we are at state 1 here, we are at state 2 here, then we have to identify where is our state 3 and that is why we know mass flow rates $\dot{m}_{a_1}$ and $\dot{m}_{a_2}$, then from $\dot{m}_{a_1}$ and $\dot{m}_{a_2}$we can take their ratios.

So, this ratio is known to us, so left-hand side is known to us. So, we can draw a straight line between them and then we can since we know their ratio, we know this is ω axis and this is dry bulb axis. So, for ω axis we can draw horizontal line from here. So, here this ratio is known, so this is $\frac{\omega_2 - \omega_3}{\omega_3}$. So, suppose this is ω_3 so this is ω_2, this is ω_1.

So, this height over here is $\omega_2 - \omega_3$ and this height over here is $\omega_3 - \omega_1$. We will cut this straight line where we get ratio of these differences equal to known left hand side and then we can know the state 3. Similarly, we know constant enthalpy line is like this, so here as well we know enthalpy which is h_2, this is h_3, this is h_1. So, this difference is $h_2 - h_3$ and this difference is $h_3 - h_1$.

So, we can again take the ratio of differences and find out the point where we will have that ratio is equal to known mass flow rate ratio and thus we can identify the state 3. We need this informations and this processes some of them for the necessary engineering applications in the design of condenser or design of the parts of the condenser. Thank you.