Engineering Thermodynamics

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Week-02
Lecture-8
Properties

Hello and welcome to our channel. We will discuss a new topic, properties. We will try to understand what properties are and how they are present in the form of diagrams. First, we will try to understand how to define pure material thermodynamically. Can it be one component or two components which we can call pure substance or pure material. After that we will discuss the physics of phase change. how the phase changes in a substance, what is its physics, we will discuss that. which we will call pure material. The thermodynamically, it means that if you take any component based substance, whether it is one component or two components, if you keep it in a container, then its composition, i.e. chemical composition, throughout, whether you can measure it in any container or any place, or the composition of the component should be fixed It means that if you talk about nitrogen then nitrogen is one component and nitrogen is one component and here if it is kept in a container and here you can see its composition and if we call the composition x_{N2} then it will always be 1 because it has only one value its composition is 1 Because it is only one component, that's why its composition will always remain the same. If you take air, which is a mixture made up of many gas molecules, but we call it pure component, pure substance. We call it pure substance because if you put air in a container and here you ask what its composition is. Suppose this is A and B. Here is the composition, because there are many types of cassettes. In this you will have x_{O2}, x_{N2} and similar types. So, this A and B are different places. And if you take out the composition of this. You can extract various types of equipment like GCMS, gas chromatography, etc.

If you extract these, the value will be same in both places. This means that if you have kept this pure substance in a container, then if you measure its composition in any place, then it will be equal. such conditions are called pure substance. Now let's talk about water. Water is kept in a container where there is liquid and vapour. Since water is only one molecule, it is one component. But the phase is different. one has vapor and one has liquid in this condition, this composition if you measure here and here Will it remain the same? What is the answer? Yes, it will remain the same because it is the same component. It will remain the same in both the cases. That is why in such a situation where the conditions are different but there is one component substance and one molecule type then also, we call it pure substance. But now let's talk about where the previous example was the same condition. But here we are taking an example where we put a temperature and pressure condition which changed the condition. In this situation, vapour and a liquid are formed. So, can we call it pure substance in such a situation? Can we call it pure product? And the answer is No, we can't say why because if you take out the position here and here at this point suppose this is A and this is B Will the composition of A and B of the vapor and liquid be equal? The answer is no, it will not be equal. Because oxygen and nitrogen are vaporized in different conditions. They are made in different ways. That is why the amount of vapor in it will be different. The composition of the vapor will be different from the liquid. Due to this, you cannot call air a pure substance. Now let's move ahead. The solid molecule is in one place, and it vibrates on the other side. That is why its representation is shown to us sometimes. So, you are putting a spring in it. The reason is that the reason is that the molecule will vibrate in this way But the position of the molecule will be in the same direction and will vibrate in this way The reason is that the molecule will vibrate in this way Because the force of the molecule will make the molecule vibrate in this way It will repel, which means it will be a different force. And if it stays away, it will be attractive, so both these types of forces maintain its position. And this condition is also different. It will become solid only at a specific temperature or pressure. So, this is also very important. When you increase the temperature, it can change. Sometimes solid can become gas depending on pressure but in general this position is here because in solid when molecules are far away they will not be visible because of volume increase So it behaves like an ideal gas. But when it comes close, it is attracted. It is acoustic. But when it comes closer, it repels. It is repulsive. So in between, the temperature pressure is such that both are balanced. The repulsive forces of the attractor balance the forces. That's why the distance is maintained. That's why the molecules here fixed and moving So this is how it is made in solid condition. But as I said, if we increase the temperature of the solid, then the position gets so kinetic energy that it melts. It gets liquefied. It becomes liquid. So, in this case, the situation is like this. There is no fixed position here. and if we increase the temperature, the gas molecules will increase. So, this is how the temperature changes, just like the heat.

Similarly, you can change the temperature by increasing the pressure. If you look at it, as we said it vibrates here, here it is random, it can go in any direction, that's why we call it random. And it is seen more in gas molecules. The molecules are in the gas phase and in the gas state. It is very random; it can move freely anywhere. Because the distance between two particles is so much that it... It has less constraint to pull and stop the fluid. That's why it can move freely. And when it collides with the solid, it changes direction. The same liquid has more collisions. And it can't move in solid. Because it is stuck in its position. So, these are the three major conditions of any substance. Now we will try to understand what is the physics that changes the condition of pure substances. In pure substance, we can give anything, but since water is the most important for us through application, we will take water as an example.

First, we will understand that when water is in liquid state, when it is not vaporized, i.e. if you keep it in liquid and automatically do not make vapor such a condition is called compressed liquid or sub-cooled liquid. So, let's say you have kept water in one atmosphere and kept it at 20-degree room temperature. So, the water will remain in the liquid state. But on rainy days, if you keep it in the room, it is different because if there is a big atmosphere in the room, there is water, oxygen, nitrogen, etc. But here we said that we will maintain one atmosphere with a piston. So here we said that one atmosphere, piston cylinder geometry is there. This piston is made up of one atmospheric pressure. If you had kept it in the room, then this water would have evaporated gradually. Because its reason is different. We will discuss it later. But here, if you talk about pure water, then one atmospheric pressure at 20 degrees Celsius. We have shown this with the help of piston cylinder. Here we have a piston with a pressure of 1 atmosphere. 20 degrees Celsius is the initial condition. In this way, it is liquid. Now we are transferring the heat. If we are transferring the heat, we know that water boils at 100 degrees Celsius. So, this compressed liquid will remain until it reaches 100 degrees Celsius. And as soon as it reaches 100 degrees Celsius, vapor will start forming from the liquid. So, the first molecule will be vaporized. It will try to get out of the liquid and vaporize. In such a situation where it is ready to form vapor, we call such a situation saturated liquid state. such a condition is called saturated liquid. In the case of water, it is 1 atmosphere, 100 degree Celsius. If we change the atmosphere, the temperature will also change. We will talk about that later. Now we have reached the saturated liquid. Now what happened slowly is that we still transferred the heat. And it is maintained at 100 degrees because this water is coming into the weapon from the liquid. In this situation, when both the molecules are in this state, we will call it saturated liquid vapor mixture. And it will keep taking heat until the last molecule remains in the liquid. And when the whole thing changes, it will come out of the saturated liquid vapor mixture and will become saturated vapor. Because all the molecules will now go into the vapor. State 4 is the state of saturated vapor. State 3 is the mixture of both states. That is why it is called saturated liquid vapor mixture.

Now we have reached state 4 where this is the vapor. And in this state where this is just the last molecule vaporized in that state, we will call it saturated vapor. If we remove the heat in this situation, then the vapor molecule will start to condense. That is why we call it saturated vapor. It is not only that your last molecule of liquid has formed a vapor. But in such a situation where it is saturated vapor, if we remove a little heat it will start to condense, it will start to form a liquid. Meaning, a molecule will come out from here and become a liquid. So, this is a definition of its Saturated Vapor. If we put more heat, the temperature will only increase. Because the temperature will not change. The vapor will remain. In this way, it is called superheated vapor. Now we try to present it in graph form. You must have noticed that the temperature and the volume are changing. So, in the form of temperature and volume, we will show this process. We started at 20 degrees and 1 atmosphere. So, we start at P equal to 1 atmosphere.

Here we were at 1, here we were at compressed liquid. And from here we started to give heat and here we reached 100 degrees. It is linear, as shown in the straight line. Because the volume increases like this. The temperature is increasing, and the volume is also increasing. And here, the first molecule was vaporized. And this particular line is called the saturated mixture. Vapor liquid mixture. And the state of 3 was shown here. Here you have two waves, vapor and liquid. and this is your saturated vapor liquid. Now, if you hit all again, then at this point 5 is superheated. So, this whole line you can see is superheated. These are all superheated states. You can take any point in this; this is a state of superheated vapor. Similarly, in this, you can take any point in this, this point, then you have saturated liquid vapor mixture. Okay? This is the thing of about one atmosphere. If we change from one atmosphere to two atmosphere or hundred atmospheres, then what will happen? Ok. We have already written it here. This is the temperature versus vapor. We had done it in one atmosphere. One atmosphere is 100 kPa, which is 0.1 MPa. So, this was here. If you work, then this point, at which point this is, at which point this is saturated liquid point at this point and at this point you can see the horizontal line this point is called as T-Sat as we said here this is one atmosphere T-sat is 100 degrees Celsius But this at one atmosphere. Similarly, this T-sat will be at point 1. Similarly, this T-sat will be different. Notice that as pressure increases, your T-sat will increase. and if the pressure is decreasing, then the T-Sat is decreasing. But another thing you should notice is that at the point where the T-Sat is, as you can notice on this, it is less pressure, so the T-Sat is less. But at the point where the saturated liquid is, the volume of this is also less. If you increase the pressure, the volume of the saturated liquid increases. If you decrease the pressure, the volume decreases. Similarly, this is the volume of saturated vapor. on low pressure, this will be more and on high pressure This will be less. As the pressure increases, you notice that the line that represents the saturated vapor liquid ends at one point. And this point is called the critical point. At this point, the vapor and liquid look exactly the same. You can't tell. You can't separate them. That's why it's called the critical point. We can't distinguish them. We can't tell. You can't differentiate between liquid and vapor. And on top of that, on the pressure, you won't get any saturated liquid vapor. Meaning, there is no change in any condition. There is no change in the distinct condition. From somewhere, from the liquid, it doesn't look like vapor is forming properly. But this is for sure. If this is compressed liquid, from here, from the compressed liquid, it goes directly into the superheated vapor. If you look carefully. There is no change in this, the molecules are slowly coming out, the changes are slowly increasing, the distances are increasing, and the structure is changing, but it is not like the vapor is changing in density as we have seen. And normally when there is a change, you can see it differently. Like this is a vapor liquid, you will see it. And the line we have drawn in between, this is called the interfacial region. You will see it in the miniscule experiment. So, this is the plot between T and V And this region is your Superheated region This is your Sub-Cool region This is superheated region. Sometimes it is also called a supercritical region. Because it is at the critical point.

If we simplify it in a simple way, we can say that this is your temperature versus specific volume. This is your phase change plot. It will always look like this. In which the pressure should be less than the critical pressure. This is the inflection point. This line is the distinct change. It will not be visible to you. And this is your line. Pressure greater than pre-critical. So, this is your line. This is the liquid region, and this is the vapor region. So, this is a simple form. At this point, the temperature will be T critical, the volume will be V critical and the pressure will be P critical. You must have noticed that T-sat increases as pressure increases. You could see it in this particular graph. So, we will discuss this in the end. We know that the temperature is Boiling point temperature means to become a gas molecule or a vapor molecule. Formation of vapor molecule means formation. This is what we call boiling. So, in one atmosphere, water boils at 100 degrees Celsius. So, if we change the pressure, then the T-sat changes. As we saw. The pressure increases, so the T-sat also increases. And this is not linear, this is a curve. As we saw, Water is not linear. It is normal. And at some point, it will become PCI or TCI after that, your phase will not change so, usually, you can see the behavior of any pure material in which T-Sat and P-Sat behaves like this now, you can understand it as Why do we take time to cook food? If you simply turn off the stove in an open container. Because you notice that the pressure in the anus will be less. So, when the pressure is less, the boiling temperature will also be less. It will start boiling very quickly. And when it boils, the steam will start flowing if it is kept open. So it means that the high energy fluid is flying So your boiling, your cooking will not be possible because it has flown away And if that thing takes time, then the heat transfer of your energy is in the liquid and it is cooking your food That's why the pressure cooker is used So in the pressure cooker Your pressure is maintained and your weight is increased. That is why your boiling temperature and T-Sat has increased. That is why the heat transferred to the liquid is very long. That is why your food cooks quickly. This is a very important diagram to understand these things. Let's hope you understand pure substances and how physics changes. So that's it for this lecture. We will discuss PV and other diagrams in the future. Till then, bye.