Heat Treatment and Surface Hardening (Part–1)
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Lecture Number 04
Critical Definition and Phase Transformation Thermodynamics and Driving Force

Hello, let us start fourth lecture. Now in this lecture we will get into the fundamentals behind heat treatment and whenever we talk about fundamentals, we need to see what fundamentals.

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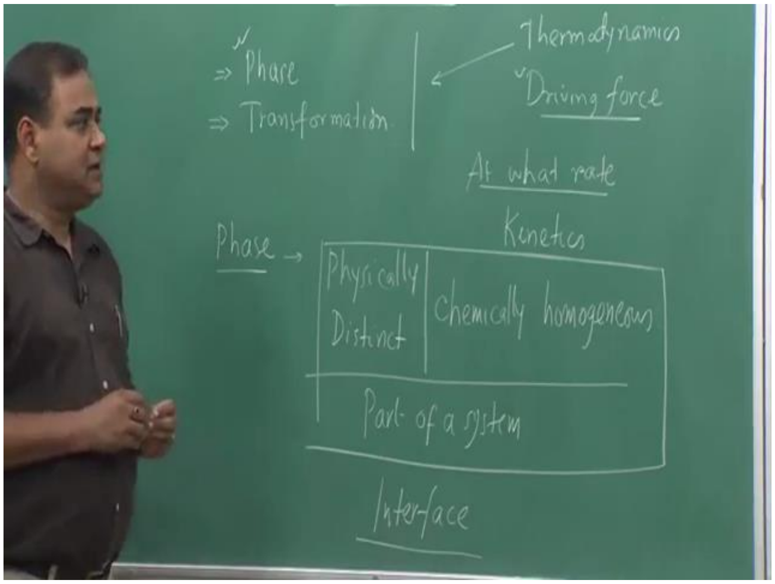

Now as we have seen that four factors, phase, transformation and then here we see thermodynamics means whether a particular phase transformation is possible or not, thermodynamics will decide and when, whenever we talk about possibility, we talk about whether there is any driving force for the transformation.

So the driving force, now once we see the driving force that means a particular phase transformation is being driven by some particular parameter force. And then, once we see that yes the possibility is there or then, we need to look at, at what rate? At what rate? And whenever we talk about rate of phase transformation, we talk about kinetics. So let us first see the phase transformation part, from the point of in the angle towards (wh) in order to see the phase transformation we need to first check thermodynamics, we will talk about that.

Before we start this driving force, let us have some definitions. The definitions are phase, this is this needs to be defined. The classical definition we call it as physically distinct, physically distinct then chemically homogenous part of a system, part of a system in has to be part of a system and then we call it a phase. Now whenever we talk about part of a system, that means one system has to defined first and out of that system we have to see what is that part, now how do I take that part out? In order to take that part out, we need to see that is there any demarcation between that part from the other, from rest of the system.

And that demarcation is nothing but interface, interface. So while defining phase, all those keywords are necessary, that means it is a physically distinct, that means its appearance would be different chemically homogeneous. So in that particular phase at every point, we can have a similar concentration composition and part of a system, means it should be a part of go whole system. And whenever we are talking about the part of a system, we need to see whether that part is covered or separated from the rest of the system with an interface.

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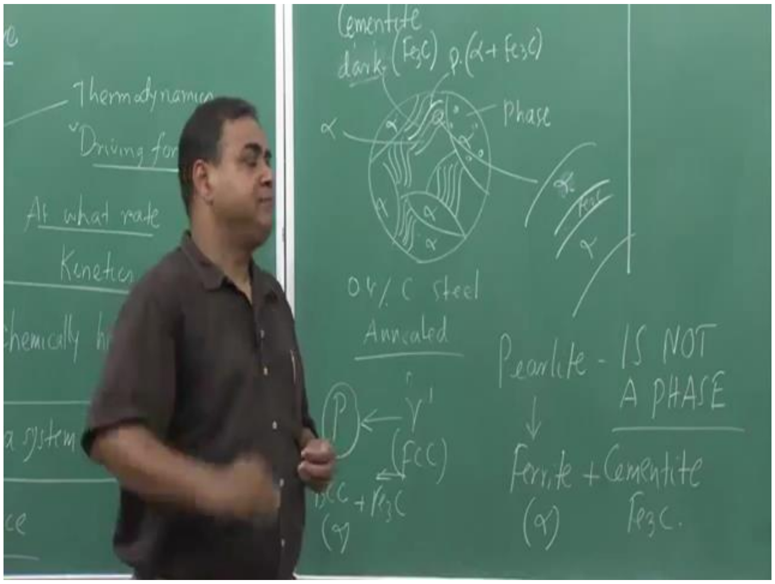

Now in order to appreciate this definition, let us take a small example and we will talk about example like a steel and in the steel, if we see a kind of a 0.4 percent carbon steel and if it is completely annealed structure, means its furnace cooled then the structure would look like, so there would be grains, and at the same time there would be perlites. So this is alpha, this is perlite and the perlite is also a mixture of ferrite plus fe3c which is cement. Now let us see which one is a phase, now here if we see alpha which is the BCC phase in steel which is also nothing but interstitial solid solution of carbon in iron and we see that this phase is separated from rest of the system if this one is the system, rest of the system with an interface which is the grain boundary.

Now we need to look at what happens, if it is rest of the system that means it is the part system, that part is fulfilled, this part of the system is fulfilled. Now we need to see whether other things are fulfilled, now if we see at different sections, if we see the concentration of carbon in different sections, we would find that the concentration of carbon is almost same is same at every point within this particular section, so that means, it is chemically homogeneous.

Now the first one which is the physically distinct and if we see under microscope and as we have discussed in previous classes, lectures that whenever we try to see microstructure of a steel under micro scope, we need to electrochemically age it by a nital solution and then we see under microscope, we will see this kind of structure and this phase would look right. So that means and rest of the these phase would look greyish, so that means these phase as if distinct physical appearance, that means it looks bright. So that means it is also physically distinct, okay, so that means we can say that this is a phase. Now, let us this part was also alpha, this is also a phase, this is also a phase, this is also a phase, this is also a phase, this is also a phase, this is also a phase. But now what happens in the perlite? In the perlite if we see that this particular thing we, if we see under microscope, we will see that this particular stuff would look like a white strip, white strip.

And this is nothing but Fe3c which is cementite and this part which would look, so this, this is not white rather I am I am wrong, this is this will not look like a white this is a strip which would look like a dark strip and this will look white, so just wrong this is the dark part I am sorry this would be the dark part and then these section, these section would look bright. Now here, these are nothing but alpha again this is alpha but it would have a different composition than this, okay we will come to that why this have different composition than this.

Now once we have this, now you have a dark phase which is cementite, we have a bright phase which is alpha and at the same time if we blow it up at this particular joint, if we blow it up, we will see that this is alpha this is Fe3c and this is Fe, this is alpha again. So that means, this is an interface, so that looks like again this particular zone is separated from the rest of the system with an interface. And also if we see at different points within this, if we see the composition we will see that the composition would be (ente) will be same everywhere the carbon percentage would be 6.67 percent and that means this is chemically homogeneous and also under microscope it looks like a dark phase, that means is physically also distinct.

So this is a phase. Now adjacent to that, that alpha is also surrounded by a boundary and it is separated from rest of the rest of the system and every point in this would have same composition. So that means it is also chemically homogenous, physically distinct part of the system separated by a boundary from rest of the system. So that means the perlite is not a phase, rather it is a mixture of two phase. So that means it is a phase mixture. So never make any mistake like that, that perlite is a phase.

The perlite is not a phase because it is not a distinct part, rather it has two distinct part and those two things are ferrite and cementite and this ferrite is called alpha and cementite is Fe3c so it is a phase mixture. So now we understand what is phase. Now, whenever we talk about phase, it can have different distinct nature like let us say a pure component system, let us say (se) a pure metal, let us say aluminum and if we take it to (ss) (be) beyond (six sixty) 660 degree Celsius, then it would melt, okay.

So it would have though the composition would be same, that means the pure metal, but at melting point, beyond melting point it would be liquid, below melting point it would be solid. So that means, it has two distinct nature, though the composition is same but physically they are two distinct phases, okay. So that means it is a liquid phase, is a solid phase. So composition can be same, but at the same time we need to see whether they are physically separated or not. So we see that if we have a pure metal, aluminum, a liquid as well as solid, then we say that it is a phase mixture again and where we have two phases, one is liquid, one other is solid.

Similar like water, ice water mixture, so the ice water mixture, ice is a phase which is a solid phase and liquid water is another phase which is a liquid phase. Now when we talk about phase transformation, then we always see that if we heat, if we take ice out from a refrigerator we see that at normal temperature room temperature in Indian context, it melts, it melts means solid transforms to liquid or other way around, if we take the liquid inside liquid water, inside refrigerator after sometimes it already frieze, it becomes a solid ice. So that means there is also a transformation is taking place. That means solid to liquid as well as liquid to solid. You can also have a other transformation as solid state transformation. For example, this perlite transformation happen perlite which is alpha plus Fe3c that transformation happens from gamma which is FCC iron.

So from there, one BCC phase alpha and one Fe3c phase appears. So both the phases are solid this is also a solid phase, so that means it is a solid state transformation. So we can have solid state transformation, both the phases could be solid, the transforming product is a solid and from where it transforms that is also a solid. But we can also have a liquid solid transformation, the transformation product could be solid and then it melts then it forms liquid or the other way around when liquid solidifies we call it a solidification that time transforming product is solid but that from where it transforms that is a liquid.

Now in order to try, in order to see phase transformation, we also need to specify whether it is solid liquid transformation or solid solid transformation or gaseous solid transformation or gas liquid transformation anything can be possible. Now whenever we talk about that, then complication arises whether it is a pure component, whether it is a mixture, whether it is a solution all those situations would arise. Now in order to simplify those complications, we can go one step ahead, one step, one step by step.

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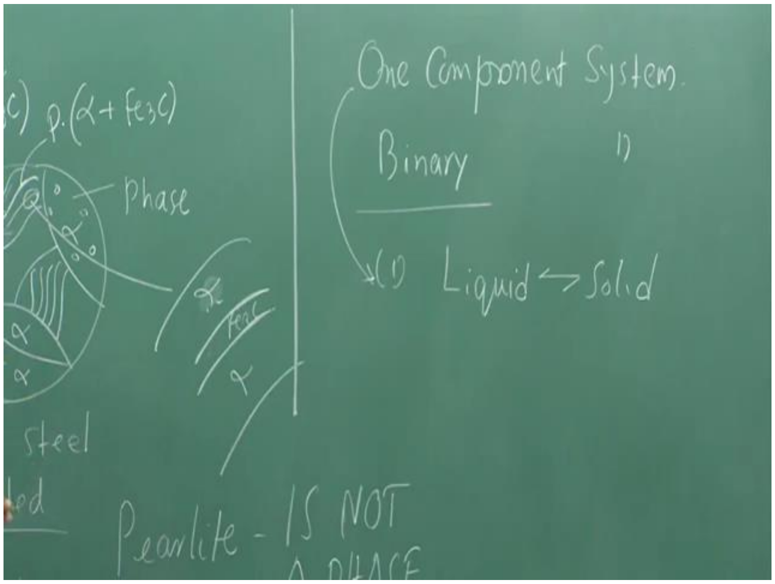

For example, initially we will consider one component system, one component system and then finally we will go to binary system, binary system and later on we would see that if we have more than two, if there are two components we call it a binary, if we have more than three two components we call it ternary if it is three component. Then as we increase the number of components, thing become, things becomes a complicated. So in order to address those complicated system, we need to go and understand what is the thing in, what is there in a simple system which is one complicated system.

Whenever we talk about one component system, in most of our engineering applications we talk about solid liquid transformation, okay. Classic example is casting, okay, the casting what we do? We melt metal, we form a mould and inside that mould we pour the liquid metal and the liquid metal takes the shape of that mould and we get desired shape and little bit of machining, little bit of processing, okay, we get to have a final product. Examples, for example engine blocks, engine heads those are all cast products those are complicated and this complicated products can be obtained by casting.

Now so first consideration would be one component system, and in that one component system, we look at liquid solid transformation. And whenever we talk about liquid solid transformation, we take both, that means liquid transforms to solid or solid transforms to liquid. When that would take place? Okay, and that, and why that should take place? In order to answer that, we need to get to the fundamental aspects which is driving force. And whenever we talk about driving force, we talk about thermodynamics, okay.

Now after this, let us get into some of those basic thermodynamic functions, okay. We will not talk about thermodynamics as it is thought in thermodynamics course. We will just take those things, which will be useful for our purpose in heat treatment. While understanding the concepts of heat treatment, we will be talk talking about some functions, okay. So let us see those functions, driving force.

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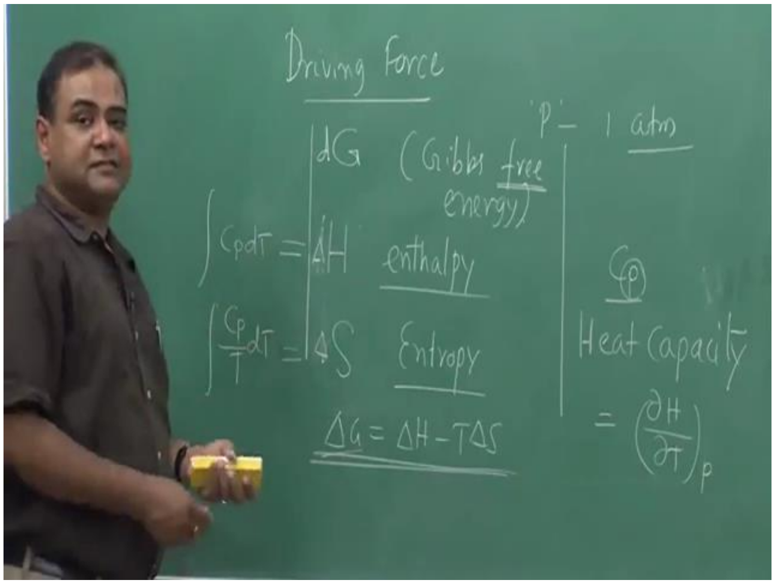

Whenever we talk about driving force and in normal solid liquid condition, that means in the solid and liquid we can call it, we can term it as incompressible solids or incompressible material, okay.

So that case, our normal practice we maintain pressure constant at 1 atmosphere pressure, okay. And that time, the driving force is decided by term G, which is Gibbs free energy. This is a very very important function which would decide whether a transformation would be possible or not. Now whenever we talk about Gibbs free energy and that time why it is called free energy? Now we could have called it Gibbs energy, would have been fine, but we also incorporate one word called free.

This free term comes because this particular free (ener) this particular energy term would be available to do some useful work that is why it is called free energy, in a system we have lot of energy which is decided by the total heat content of the system which is called enthalpy, there is one more term called enthalpy, okay. But this total heat content of the system would not be available to the do, to do, to do the work, rather the part of that particular work will be available to do the work and that is free energy.

And in order to decide how much we do we get out of the system for doing work, then another term we have to consider which is called entropy. So these three parameters all are energy terms, these three functions would be required in order to understand whether a phase can transform to other phase. And in order to decide that, we need to see what in order to we need to find out what would be the values of those particular functions. Absolute value of these particular functions cannot be obtained.

And at the same time we need to have some measureable quantity, which we can measure with the help of some experimental facilities, okay. And then that measureable quantity we can use in order to find those functions. And whenever we try to find those functions, we try to find the change in values, we can decide what could be the we can measure what could be the change in values. So that means, we can measure change in enthalpy, change in entropy and change in Gibbs free energy, okay. And in order to do that, the measureable quantity what we have is basically Cp, which is the heat capacity, heat capacity.

And this heat capacity, because why we are calling it Cp, because we have kept the pressure constant because this is a condense system. So we will be (consi) fixing the pressure and that is what it is called Cp. At constant pressure, what is the change in heat capacity? So heat capacity definition wise is nothing but dh dt p, which is the change in enthalpy or the heat, amount of heat with temperature at constant pressure. So that means from this relation, we can say that this we can find out from Cpdt, this we can find out Cp t dt, okay.

So whenever we take this, so that times it becomes this, it becomes this. So that means whenever we integrate, it is to be finite quantity. Now what is the relation? Once we have these two, we can find out del g from this formula. So that means, we calculate this one individually, we this calculate this one is to be calculated individually and then finally at the temperature why would like to find out the change in Gibbs free energy, we just use this formula, okay.

So now, if we try to see graphical representation of all those things, we can also do it, okay. So in order to do that, let us plot the change in Cp as a function or temperature at constant pressure and change in H and enthalpy, enthalpy and as well as entropy.

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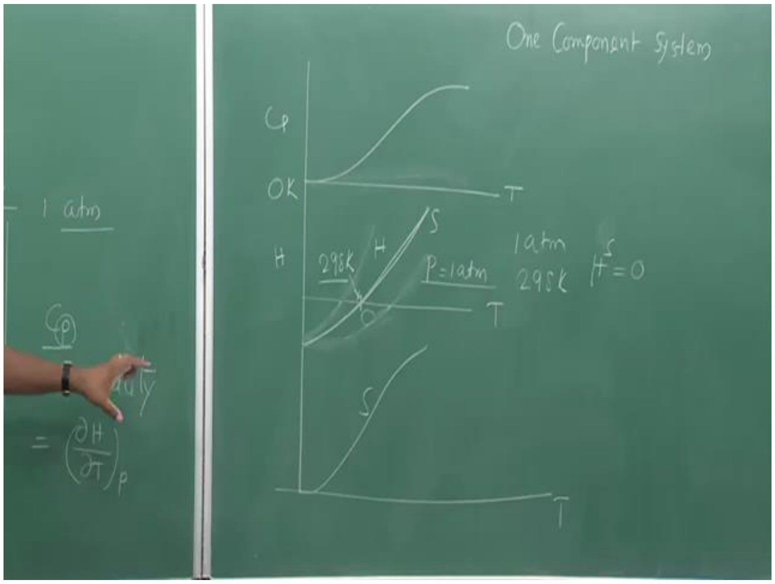

So this is my temperature, now if we try to see the variation of Cp, the Cp varies in this fashion, this is Cp as a function of temperature and this is zero kelvin, this is in kelvin scale. Now whenever we have this Cp, we need to specify whether it is a one component or two component what system it is.

Now, as we have mentioned before that initially we are considering one component system, one component system, let us say pure metal, okay. So the pure metal that means we are considering it is 100 percent pure, through in the last lecture, last two lectures I thing in the first lecture or second lecture we have discussed that getting 100 percent pure metal is absolutely possible and the reason is the entropy term. Well if we come across that, we will discuss otherwise we will just keep continuing with our understanding of this free energy and other things in order to get to the heat treatment concepts.

Now if we have Cp variation like this, then enthalpy varies like this, this is H, this is temperature again and entropy varies like this, so this is S, this is H. Now this H is crossing the temperature line and when it crosses it becomes it takes the value of zero. So the enthalpy value becomes zero. Now this zero can be anywhere is it? At any temperature it can assume a zero value, but in thermodynamics, in order to find some value we have to setup a reference state.

For example, in order to measure a height of a building, in order to measure the height of the building, we need to see that from the death end, that means from the first floor what is the, rather from the floor of the (la) floor of the earth, what is the height of that particular building? But let us say I instead of and that time it becomes let us say 100 meter and let us say I dig up and then measure the height from the basement I get 110 meter.

So now, who is right? I am also right that other person is also right. So that means, in order to make both the right, we need to specify what is the reference, and the reference state is in the stablest condition of a pure substance at 1 atmosphere pressure and 298 kelvin, H takes 0 value. That means the stables most stable substance in pure metal is basically solid. So the H solid would be zero when temperature is 298 kelvin and pressure is 1 atmosphere pressure. So that means, if we consider this is the solid line, this is the solid enthalpy change, this temperature would be 298 kelvin, okay.

And that time pressure is 1 atmosphere pressure. And this is nothing but the standard state. So this is my reference, this is the reference data or the data value. And from that we measure the value of enthalpy of other substance or the same substance at different temperature. So let us stop here, okay, we would continue on the same topic in our next class. Thank you very much for listening.