Heat Treatment and Surface Hardening (Part–1)
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Lecture Number 19
Phase Diagram and G vs X plot

Hello everyone, let us start nineteenth lecture.

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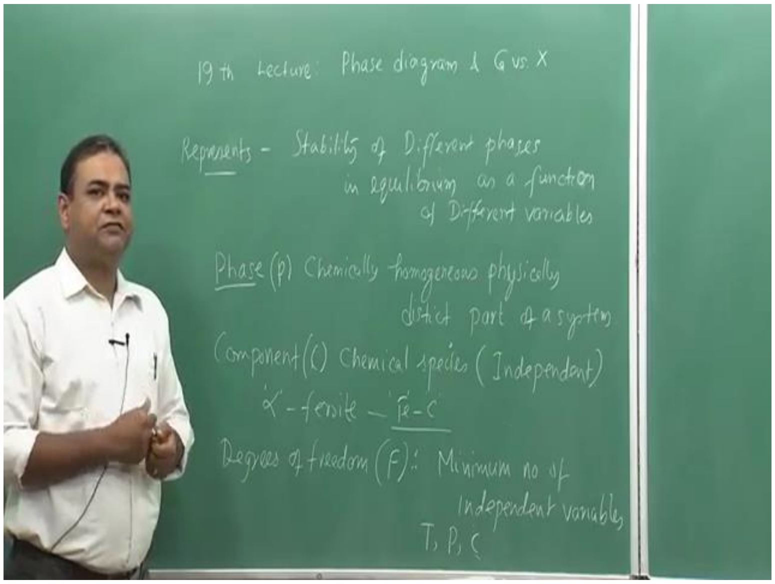

19 th Lecture: Phase diagram & G vs. X

Represents - Stability of Different phases
in equilibrium as a function
of Different variables

Phase (P) Chemically homogeneous physically
distict part of a system

Component (C) Chemical species (Independant)
'α - ferrite – 'Fe-C'

Degrees of freedom (F): Minimum no of
independent variables
T, P, C

And here we will talk about phase diagram and G versus X plot, so this phase diagram we will talk and then G versus X plot will be needed which is the free energy composition X is the mole fraction, that diagram would get me to derive to draw a phase diagram. We will try to draw a simple phase diagram like isomorphous system and or we can also draw eutectic system or eutectoid system.

But let us get to the phase diagram and when we talk about phase diagram we need to know what we do with the phase diagram. See phase diagram tells me that in a system at a particular temperature or pressure or let us say if it is a pure component then at a particular temperature pressure, what are the phases that are in equilibrium, okay. And at the same time if we consider a binary system, then the composition part would come into picture and that time we need to consider the composition also as a variable and that time we need to see at a particular temperature or at a particular pressure what would be the temperature and composition variable condition.

And that time what would be the number of phases that would be in equilibrium. So it talks about stability of different phases. So the phase diagram represents stability of different phases of a system, of course of a system in equilibrium as a function of different variables**.** Now whenever we try to and this phase diagram, we can represent those stability of different phases in the form of a pictorial view and that time it becomes a diagram defecting stability of phases.

Now in order to get to a little bit little bit more about phase diagram, we need to understand few parameters, of course first thing it comes phase as we have understood before that chemically homogenous physically distinct part of a system and we have already explained this phase in the earlier lectures and that time this chemically homogenous physically distinct part of a system will be surrounded by an interface which will separate this particular part from rest of the part of the system.

Now then, we have to see the components, component they are chemical species of course, chemical species constituting the system. But this chemical species they must be independent species, that means for example if we consider a phase like alpha phase in case of iron which is ferrite. So in the ferrite we have iron and carbon, so that time ferrite is not that chemical species because it depends on iron and carbon, so that time iron and carbon will be my two components. And then chemical species that means they should be independent component.

And then we have degrees of freedom which we consider as F which tells me that in order to dictate a stability of different phases in equilibrium, we need to understand that what will be the number of variables that will be required to define that particular stability in that (equi) at that equilibrium. So that now it tells me that it is not only the number of variables, rather it is a minimum number of variables that will be required and that too they will be independent. So minimum number of variables that will be required to define that particular stability of that particular phase.

And here, those variables are i, either temperature, pressure, composition this C is basically the composition or we can excess basically the component, so here we considering this form, this is P and this is F and this C is basically the component and the components we can mix together and form different compositions, for example iron carbon system this ferrite can exist in a different composition, for example it could have 0.001 percent weight percent carbon 2.0 to 0.025 percent carbon.

So in this whole range this ferrite can be possible, so though that case we are changing the compositions but the components would be remaining same that means carbon and iron. So now there is a relation which dictates how to calculate degrees of freedom while the phases are in equilibrium, okay.

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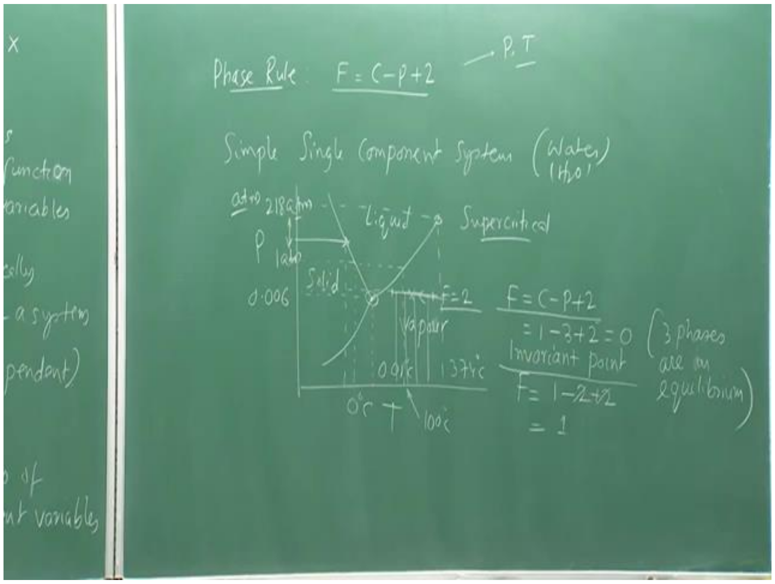

So now if we try to find out that relation, that relation is called phase rule. And the phase rule says, that F = C – P + 2 and this 2 that is coming this 2 number, that comes from the contribution from pressure and temperature, so those are external variables. Now this will tell me that what would be the number of minimum independent variables required to define the system.

Now let us get into some of the phase diagrams, that means let us see the pictorial view of the stability of different phases. And before we start the binary system, let us consider a simple single component system and if we consider water which is H_2O. Now in that case it is a single component system and there I can have a phase diagram as a function of pressure and temperature, and the diagram looks like this and here this is liquid, this is solid and this is vapour.

And now at this particular point all the solid liquid vapour phases can co-exist, so this is this (temp) corresponds to 0.01 degree Celsius around and then corresponding to pressure is around 0.006 atmosphere. So if I consider in the form of atmosphere, this is, at that atmosphere pressure. And now, we know that the melting temperature of water at 1 atmosphere pressure is 0 degree Celsius. So if I consider a (zer) 1 atmosphere pressure, this is 1 atmosphere and corresponding temperature we can get is this 0 degree Celsius. And similarly we know that 100 degree Celsius is the boiling point of water at 1 atmosphere pressure.

So we just extend it and then this one, this point is 100 degree Celsius. And of course there is one more point which is called critical point, we are not getting into that, that appears at a much higher temperature and pressure and the temperature is almost about 374 degree Celsius as well as the pressure is around 218 atmosphere. So at that particular pressure, so if we consider very high pressure and high temperature 374 degree Celsius and 218 atmosphere pressure. So this becomes a critical point where the water becomes super critical, okay. So the water become super critical.

So we are not looking at that particular section situation, but we can see that within this boundary, within this boundary solid is stable, within this boundary is liquid is stable and within this zone vapour is stable. And if we try to find out what would be the degrees of freedom at different points in this phase diagram, we can easily find out, okay. So for example, in this case, if I try to find out the degrees of freedom at this point, this point would become C – P + 2 component is one, phases number of phases are three vapour, solid and liquid so 3 plus 2 equal to zero.

Whenever we have the F value to be zero, which is the minimum value that is possible for F that suggests that the maximum number of phases that can be in equilibrium, okay so that time the maximum there are three phases, so the three phases can be equilibrium, three phases are in equilibrium. Similarly if I try to find out what would be the degrees of freedom on this line, so this F equal to again the same formula, but here the component is one that is water, but there are two phases, so 1 – 2 + 2 = 1, what does it mean? It means that one of the variables, either pressure or temperature that can be independently varied, okay.

For example if I try to see, if I fix this pressure at this particular point, then automatically the temperature got fixed, gets fixed. Similarly if I change this pressure along this axis, I can see that the temperature is also correspondingly changing, okay. So that means that one of the variables can be independently varied.

Similarly if you see at any points on this line or on this line you will see that the variable number of variables independently independent variables would be one. So that means one variable can be changed independently, okay. So now if I try to see a what would be the phase rule for the degrees of freedom at this point there will be one phase, one component. So that means the degrees of freedom at this point F would be 2 because C is 1, P is 1, P is 1 which is the vapour and that means that F becomes 2.

So that means, in order to define this particular point, we need to define pressure and temperature both, okay. So here situation was like this, if I define pressure, if I fix pressure the temperature is automatically getting fixed. But here, in order to stay at this point we need to fix both the pressure and temperature, okay. For example if I try to fix pressure, let us say let me fix the pressure, okay so that means along this particular path, I can get to any point. So you can see the temperature is also getting changed, okay.

So that means that in order to define this particular point in a single phase for water one component system, I need to have two degrees of freedom. So that means two independent variables should be required to define that particular point. So that way we can find out what would be the degrees of freedom at different points on this particular diagram. But interesting is this one where the degrees of freedom becomes zero, okay. And this point also is called invariant point. So this is in case of simple single component system and also we can say the pressure temperature regions where the solid would be stable, liquid would be stable and vapour would be stable.

So if I come back to the definition the stability of different phases in equilibrium as a function of different variables that variable that particular definition is satisfied in this particular phase diagram. Now, let us get into little complicated phase diagram, let us get into a kind of phase diagram, for example a binary phase diagram.

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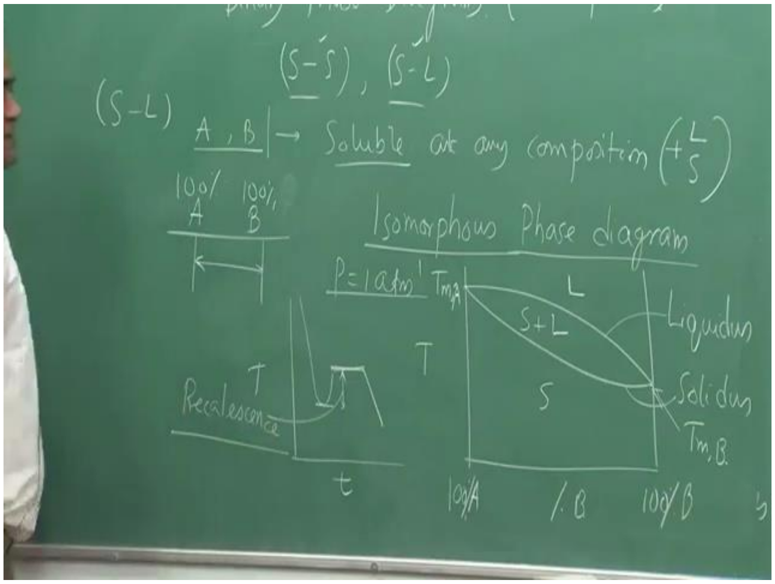

So in order to do the binary phased diagram whenever I am talking about binary, that means there would be two components and this can have solid-solid, it can be solid-liquid both is possible, both are possible. Now we are not getting into the liquid-liquid situation because our heat treatment things will be concentrating on this solid-solid and solid-liquid phase diagrams only.

For example in case of steel heat treatment we will be only looking at the solid-solid situation. But in case of let us say aluminum copper, they are also will be looking at solid-solid situation like that particular phase diagram we will be taking care of one particular type of phase diagrams which is called eutectic phase diagram, so we will be come to that. So let us consider this two situation. Now if I consider solid-liquid situation, there will be number of possibilities, okay.

So in case of solid-liquid situation, for example if A and B these are two components, okay so these two components can get mixed completely, so what it means that soluble at any composition, soluble at any composition. So in this case either it can be 100 percent A or 100 percent B, 100 percent B in between the composition range what we have. If I consider in terms of percentage of B if we start from 100 percent A and then start adding B atom into A, then A will (sol) A will dissolve B completely from 0 percent B to 100 percent B and whenever I am talking about 100 percent B that means A is absent now, okay.

So that means the completely soluble over the entire composition range, now this completely soluble at any composition this can be applicable this can possible in liquid also or in solid also. See if we consider that both liquid and solid everywhere, these two components will be soluble completely soluble, then we come across one particular phase diagram which is called Isomorphous, isomorphous phase diagram. Now in this case, we will be fixing the pressure to be 1 atmosphere, fine.

If I fix the pressure at 1 atmosphere, then I would be left with again two more variables one is (pres) temperature which is the external variable and the another one is composition because over the entire range from 100 percent A to 100 percent B, there will be any composition that is that can be possible. So now if I once I fix pressure, then the phase diagram would be between temperature and composition. Now in case of single component system since there was no issue with a composition because only one composition is possible, that means water, okay.

So that time we had to fix, we had to draw this phase diagram or with as a function of pressure and temperature. But in this case, we are fixing one particular variable which is pressure, so that means two more variables would be left with which are called temperature and composition and the diagram will be between temperature and composition. So now if I try to draw a temperature composition diagram, this is temperature, this is percentage of B let us say. So that means from 100 percent A to 100 percent B, if I try to draw the Isomorphous phase diagram, that means both the components will be completely soluble in liquid as well as solid.

The diagram looks like this, okay so in this case this becomes my liquid, this is solid plus liquid and this is solid, okay and this particular line we call liquidus and this line we call solidus. And this liquidus gives me the equilibrium situation between liquid and liquid plus solid and this line indicates the equilibrium between solid plus liquid and solid. Now this is 100 percent A, so we can term it as TmA so that the melting point of A.

And this one, since it is a 100 percent B we can term it as TmB, melting point of B because at this point, both the lines are margin together and then if I try to see temperature time cooling curve, then cooling curve will look like okay it is a single component melting point, fine. So I am this point as we have discussed that this is coming due to recalescence this is coming due to recalescence. Now let us get to this particular diagram in a little let us discuss this diagram a little more, okay.

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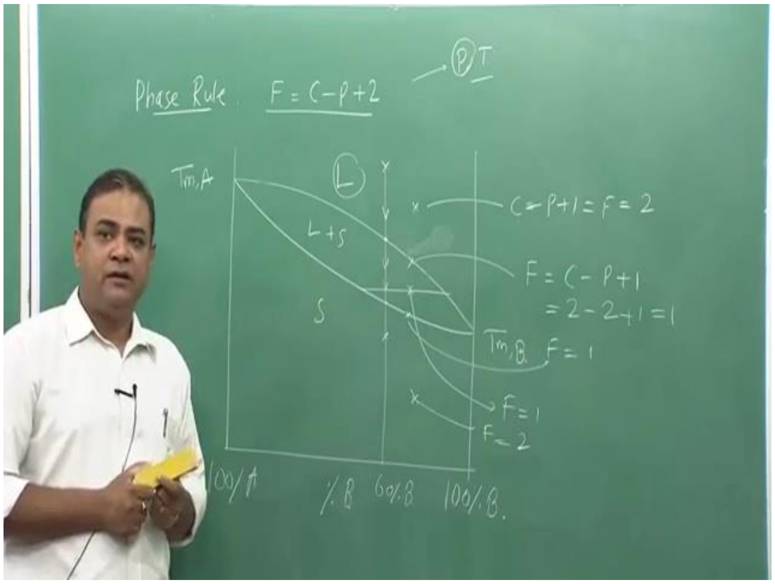

So let us come to this particular part, this is clear, now let us take one particular composition let us say this composition, so if I take this composition let us say 60 percent B and I melt this particular let us say we start with (foa) 40 percent A atom and 60 percent B atom and then I mix them together and I melt them and take it to this particular point, and at this point both the thing will dissolve together and form a single phase which is liquid, which is liquid. Now once we form homogenous liquid phase, means it becomes a single phase that means it must be homogenous.

So once we homogenize this particular thing and then create it, now let us start cooling it down and once we cool it down, once it (app) approaches this point, because this point is the boundary between liquid and liquid plus solid at this point fast solid would appear. So and as we keep (gro) going downward we will increase the amount of solid and finally once we reach to this point, a very little bit of liquid will be left but rest all will be solid and then once we reach to this single phase (ge) region, it will be again completely solid with a complete solubility of B in A.

Now if I try to find out the degrees of freedom at this point F would be equal to, so there are how many phases? There will be two phases which is, so that means if I try to see at this point what would be F, F would be equal to C – P + 2, now this plus 2 will be replaced with 1 because we have already fixed pressure. So that means pressure is fixed, so I am left with only one (compo) one variable external variable which is temperature.

So now this would be C – P + 1 and here, component there will be two component, already we have decided this A and B. So two and phases would be two because liquid and solid plus 1 equal to one, what does it mean? It means that in order to define this (proble) point I need to have one independent variable which if we fix that particular independent variable, so I will be left with, I will I will I will I can fix the second (in) second variable immediately, okay because if I fix this point, the other point the composition is also getting fixed. Now similarly if I try to see what is, what is the degrees of freedom here again you will find that it would be 1.

Now if I try to see what would be the degrees of freedom at this place, this is C equal to C – P + 1 equal to F equal to C is one 2 P is 1 and this is 1 so 2. So in order to define this point, I need to have two variables the temperature as well as compositions. But here I am fixing one variable, the one independent variable I can do with I can define the (vari) in (())(27:50) system. Now if I try to see at this point, again you will find that the F would become 1. Now you must be wondering that how can I make it F equal to 1 because this case I had F equal to 2 this case (agon) again you will find that F would be equal to 2 but at this point why it becomes 1?

Now in order to understand that, let us see a tie line construction. This tie line is nothing but a parallel line with the composition axis and that actually gives me the idea of the fraction of different phases and here we have two phases. So at along this tie line we can get the amount of liquid as well as solid and that amount in the form of weight fraction, okay because it comes from the mass balance. So the amount of liquid and solid we can calculate and once we come to this point, the liquid if I try to take this liquid to this point and then hold it, immediately the liquid would be divided into two (posi) two portion, one would be solid and another would be liquid.

And this liquid would have different composition and this solid would have this composition and this composition would be decided by the point on that particular line along that parallel line with reference to with respect to the composition axis. So this is my tie line, now since I am seeing that once I am dropping this liquid to this point, the liquid is dissociated into liquid plus solid and in this case this liquid have a (diff) has a different composition, okay.

So that is why this particular phase, liquid phase would have a different composition and this particular phase which is a solid has this composition, okay and then we can fix the amount. So we can see that at this point immediately we are reaching to these two points, we are not staying here because it dissociates. So that is what at this points we have F equal to 1, so it immediately tells me that F would be 1 at this point, okay. So we will continue our discussion on tie line as well as phase diagram, okay in our next lecture, thank you very much.