Welding Metallurgy
Prof. Pradeep K. Jha
Department of Mechanical and Industrial Engineering
Indian Institute of Technology – Roorkee

Lecture – 05
Phase Diagram of Non-Ferrous Metals and Alloy

Welcome to the lecture on phase diagram of non-ferrous metals and alloys. So in the last lecture we discussed about the phase diagram of ferrous based system especially iron carbon phase diagram. Now we will also talk about some of the important you know non-ferrous based materials phase diagram. So coming to first case you know that is of the isomorphous system and this is you know of the copper nickel system.

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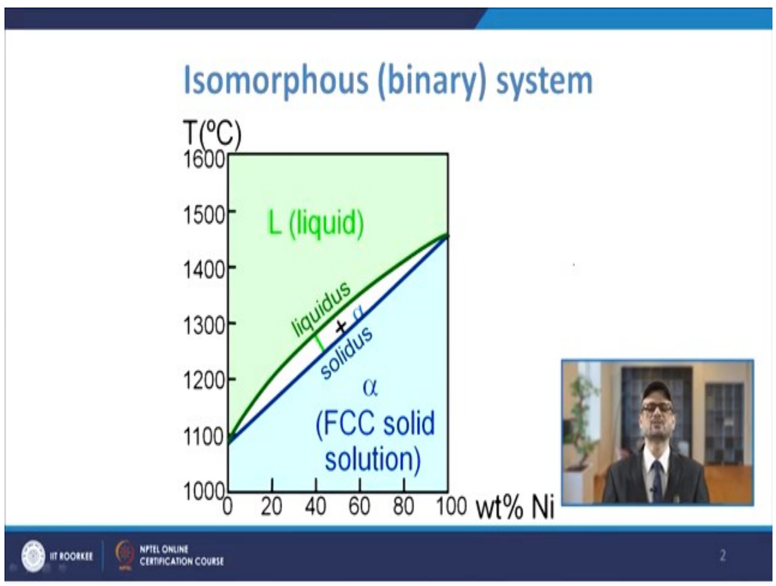

So isomorphous binary system that is we have already seen in our earlier lectures that isomorphous system is a one where you have complete liquid as well as the solid solubility and what you see is that you can see that you have the on this side you have copper and this side you have 100% nickel. So copper has the melting point of say suppose 10823 °C and it is higher.

So that way and what you see in this case that you have this is your FCC solid solution α which is there below this line and above the liquidus line you have all liquid and in between you have liquid plus α zone. So again when you come to this liquid plus alpha zone in that case you can use this tie line rule and the lever rule to find the percentage of the liquid or the α in such cases.

So suppose you have to go to any you know intermediate temperature so if you so in these cases as you know that if you come to such system.

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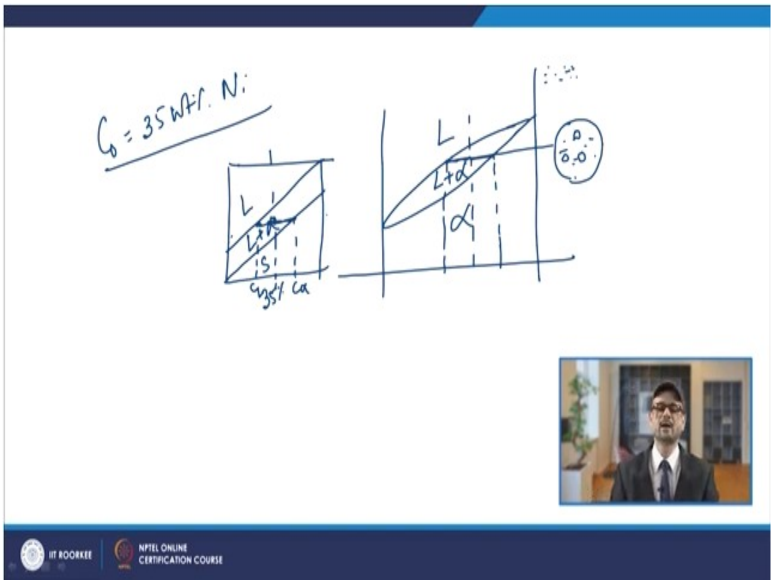

So you have seen that this is how you know when isomorphous binary system will look like. Now if you so you will have a liquid here this side you have α and this is your liquid + α. So if you come to any you know when the temperature is reached to this up to this point there is no solid formation. After that you will have the solid formation and suppose so in this zone you will have only the liquid.

And when you come in this zone you will have liquid as well as at some places you will have solid crystals formation and the solid which is formed it will be basically based on this composition and the liquid which is formed is you know so solid will be on this composition and liquid will be of this composition and if you come to for any particular you know line then the amount of solid form will be this upon this and similarly amount of liquid form will be this upon this.

So that is the fraction of the solid or the you know liquid which is calculated based on the tie line rule and the lever rule. So if suppose so this is normally you have the you know either you know copper nickel system is there which is there one example of such isomorphous system and if you suppose want to find or use this lever diagram. So suppose C_0 this will be C_0 and if the C_0 is taken as a 35 wt% nickel.

So you know at this point what you find so suppose you are taking one portion of this phase diagram so what you see is that you will have this line. Now in this this is your liquid + α zone, this is your liquid line and this is your solid line. So now when you talk about suppose 35% of the nickel so you will have 35% here. Now in this case it will be you know once you come to any point.

So you can have the value of these shows you can so wherever it touches like this so this will be your C_L and this will be your C_S. So that way our C_α so this will be your C_L and this will be your C_α and at any temperature so once you come to any temperature which is there on this corresponding to this line you will have C_L and C_S which is touching at these points that can be understood and amount of liquid will be this upon this.

And similarly amount of solid will be this upon the whole length. So that way you try to find the you know the amount of solid which is crystallized you know at any temperature and that can be found out. Now so that way now you can calculate these values.

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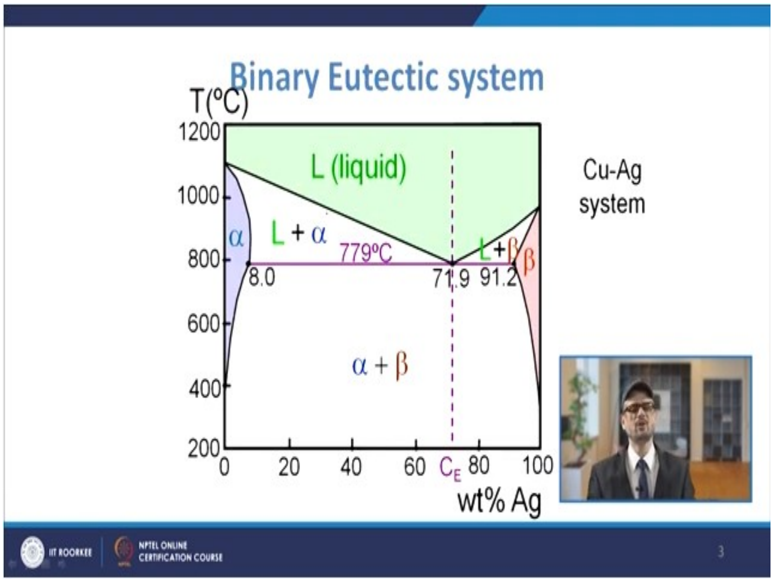

Now if you come to suppose say binary eutectic system. Now in the case of binary eutectic system what you see that you have binary means you have copper Ag system we are talking about and what you see in such cases that your this is your α so this is and this being the liquid. So you will have the liquid + α zone here. And similarly you have this β as a terminal solid solution.

You will have liquid + β on this case on this side you will have $\alpha+\beta$ which is there you know in this zone. Now this is the point of eutectic so as you see that once at this point if there is any solidification. Then this liquid will convert to the α and as well as the β. So this is typically for a copper silver system where you get such kind of traits you know for you know I mean you are getting this the glimpse of this eutectic point.

So as you see here this is for the 71.9% of the Ag you are getting this as the eutectic. So this is your eutectic composition that is CE which you are getting at this point. Now at this eutectic point you will have so this is your 8% and this is 91.2% and if you have you may have the hypoeutectic or you may have the hypereutectic composition because the point which is toward the left of this will be having the hypoeutectic composition and towards the right it will be hypereutectic composition.

Now when you are coming to any composition which is at this point as we discussed so once you are coming to any point of here so again you will be drawing a line and you will have one is α precipitating out and you have liquid of this composition and the liquid basically so as you come down this alpha you will be the composition of that α phase will be according to the point at where you are.

So that we ultimately at this point you have this α and liquid is of this composition. So you will have α and then ultimately you will have $\alpha+\beta$. So before eutectic point you are getting α and liquid and then at this eutectic point that liquid which is remaining. Now if you look at this point what is the liquid remaining. So that liquid which is remaining at this point now that will be converted to the $\alpha+\beta$.

So that way in such cases you are trying to have you know to find out what will be the different you know phases which are formed at different points. So this is for the you know copper Ag system.

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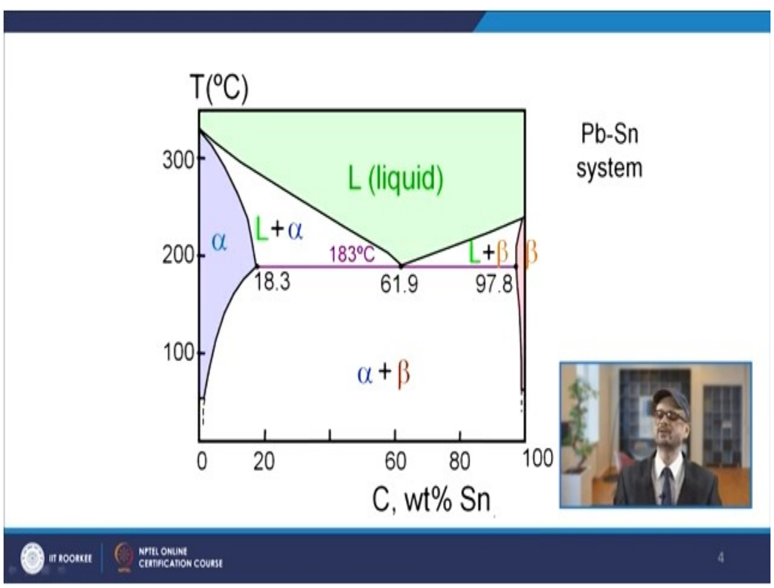

You can have the glimpse of another such system where you have eutectic reaction taking place you have again alpha the solid solution here for the Pb and for Sn you have beta and this is your you know eutectic point, so that is for 61.9% Sn. So we know that this Pb-Sn eutectic is normally used for the soldiering applications. Now what we see that in this case if you have this composition. So this it will have the solidification at this point itself just like pure metal you will have solidification.

And that will give you this $\alpha + \beta$ phase for this particular you know composition. Now suppose if you are told to find you know for the 40, 60.

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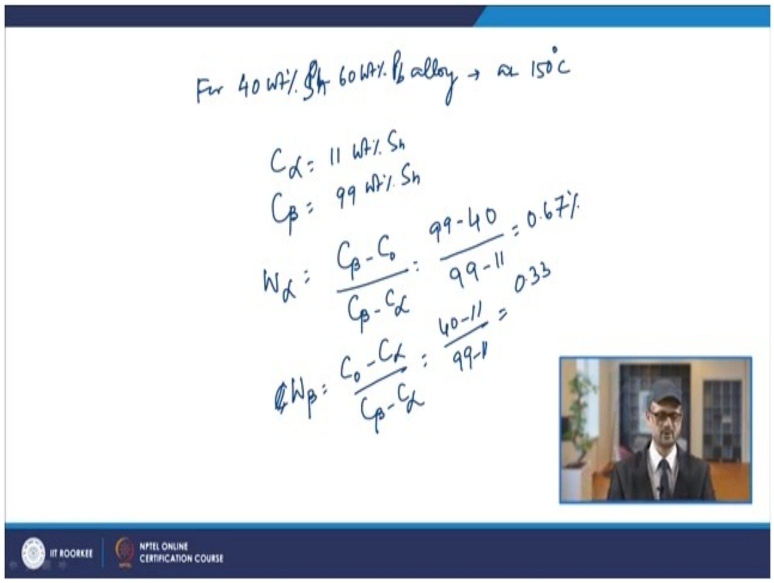

So if suppose you are asked that you find for 40 wt% you know and Pb and 60 wt% so that is 40 % Sn and 60 % of Pb alloy and that is at 150 °C. So if that is the case in that case what you do is again you have to refer to this you know phase diagram. And what you see is that you are talking about 150 °C . So 150 °C will be somewhere here.

So now in this case this your 60% Sn. Now in this case you are going to have the value of Cα and Cα if you try to find you will get somewhere close to 11 wt% of tin. So you will have Cα as 11 wt% of tin and similarly you will have C_β will be 99 wt% of you know tin.

So you can find the relative you know amount of each phase and if you try to find the weight of α so as you know that weight of α will be you know so when we talk about the weight we are taking into account the lever rule. So we will have C_β-C_0. So it will be (C_β-C_0)/ (C_β-C_α). So that way you can find and C_β as we understood it is 99 and C_0 we have already seen that it is 40% tin we are talking about it will be 40 and divided by 99-11.

So if you talk it will be you know 0.67 so it will be 0.67%. So similarly now if you talk about C_α, C_α will be you know 100 minus this. So C_α basically when you so that is your W_α and when you talk about the amount of β formed. So it will be (C_0-C_α)/(C_β-C_α). So it will be again you will find it as 50-11/99-11. So it is coming as 0.33 what do you see that this is $W_\alpha + W_\beta$ has to be 1.

So once you get this as 0.67 weight percent it will be W beta will be 0.33. Now if you take the different temperature so it was below that eutectic temperature.

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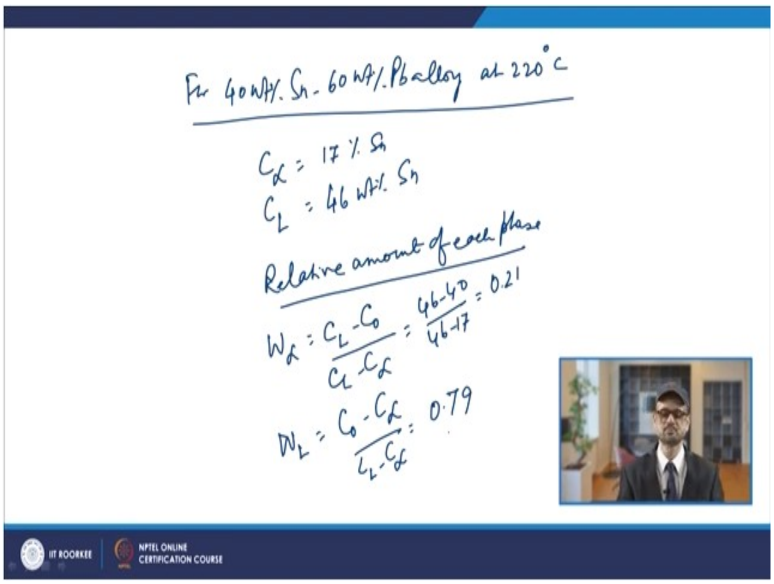

If you take the temperature say you are again taking for 40 wt% tin and 60 wt% you know lead alloy and if you are taking for this alloy at 220 °C . Now the temperature is different and now your 40 wt% tin in will be somewhere here and you are going to take at a temperature which is 220 °C . Now again in this case you have to find the $C_\alpha$and C_L.

And C_α if you look at it will be close to this. So it will be close to 17%. So in this case again you will have C_α as 17% you know of tin and if you take the C liquid now liquid will be you know 46 wt% of tin. So again you can have the you know relative amount of each phase. So relative amount of each phase can be found out. So you can have calculation of α phase as you know that α is towards the left.

So you will have the β point-C_0/(C_β-C_α). So it will be C_L-C_0. So β is not here because we are dealing with the temperature above the eutectic point so you have a liquid will point only coming out. When we are talking about the temperature below the eutectic temperature then there was β phase otherwise you have the liquid phase. So (C_L-C_0)/(C_L-C_α) and we have got you know C_0 as the 48%.

So it will be 46-40/46-17 and it is coming out to be about 21% is coming out to be W_α. So similarly you can have the liquid percentage and liquid percentage will be according to the line which is cutting the you know line towards the α zone. So it will be (C_0-C_α¿/(C_L-C_α¿ and in this case you will have this as so it will be so 1-0.21, so it will be 0.79. So such is you know the way you calculate you know these amount of relative amount of phases which are formed in the case of you know these phase diagrams.

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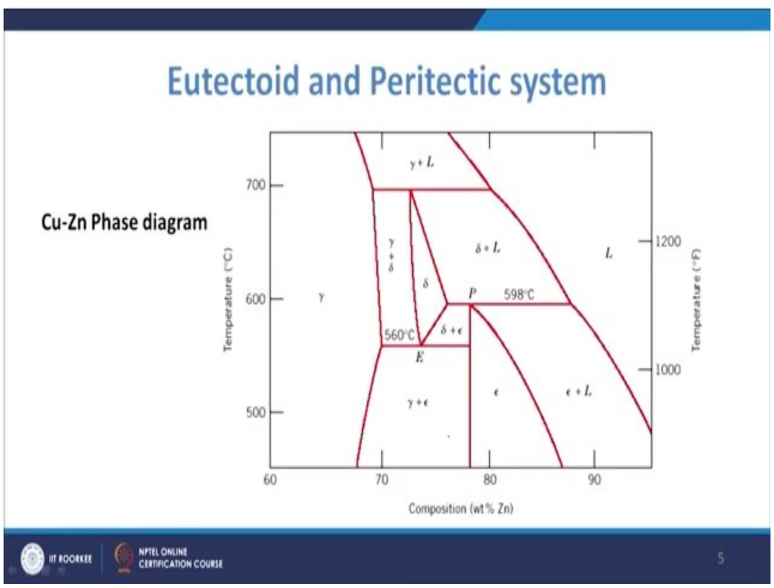

Now you can also you will also come across other kind of phase diagrams which are like you have eutectoid as well as you have the you know peritectic phase system so what you see in such cases you are seeing some you know points where you see that you have eutectoid as well as peritectic systems. You talk about the peritectic system this is a typical copper zinc phase system.

You can see that you have γ + liquid and is converted to . So that is basically an example of one solid + one liquid phase. On cooling will give you another you know solid phase that is formed in the case of the copper zinc phase diagram. Now in this case what you see this δ phase when it will be solidifying below this point it will give you $\gamma + \varepsilon$. So this type of reactions are known as the eutectoid reactions.

And what you see here in the in this case that the solid phase is converting while getting cooled it will lead to the $\gamma + \varepsilon$ phase. So you will have you know the eutectoid reaction. So peritectic and as well as eutectoid both type of invariant reaction is there in the case of copper zinc phase diagram.

So when you deal with you know such phase diagrams even for non-ferrous systems typically you see that a lot of you know such cases appear where you see that you have reaction products you know as you come down you will have the different reaction products because the solubility will be different as the temperature is increased. If you talk about the other systems even like copper aluminium system there also because on that itself.

Because when you are in a higher temperature zone then solubility of one phase into other is more while when we decrease the temperature the solubility you know is decreased so what happens the supersaturated phase will you know again in that the precipitation is likely to occur. And based on that we are in this concept is utilized for you know exploiting or bringing into the hardness that is known as precipitation hardening.

And if so we can also see that when we talk about the eutectic systems you may have you know the solidification or the transformation for the eutectic composition or it may be for any hypereutectic you know composition. So if you talk about suppose say if you see the you know Pb-Sn system.

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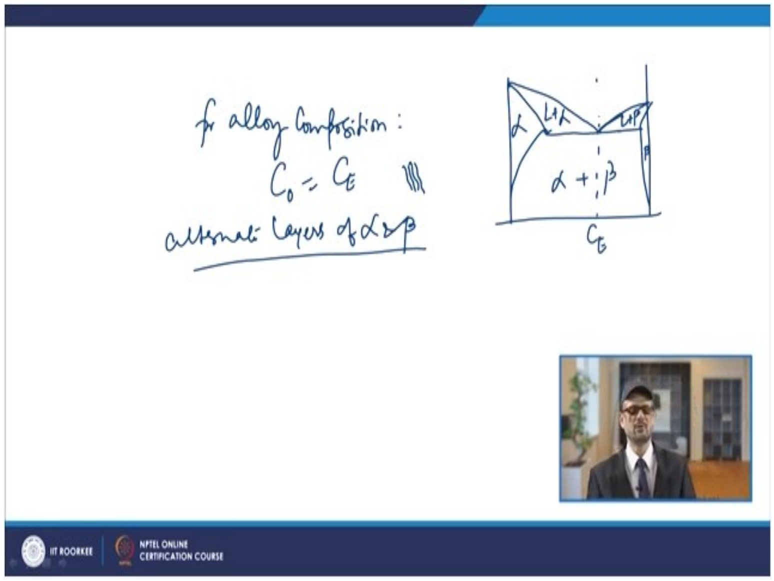
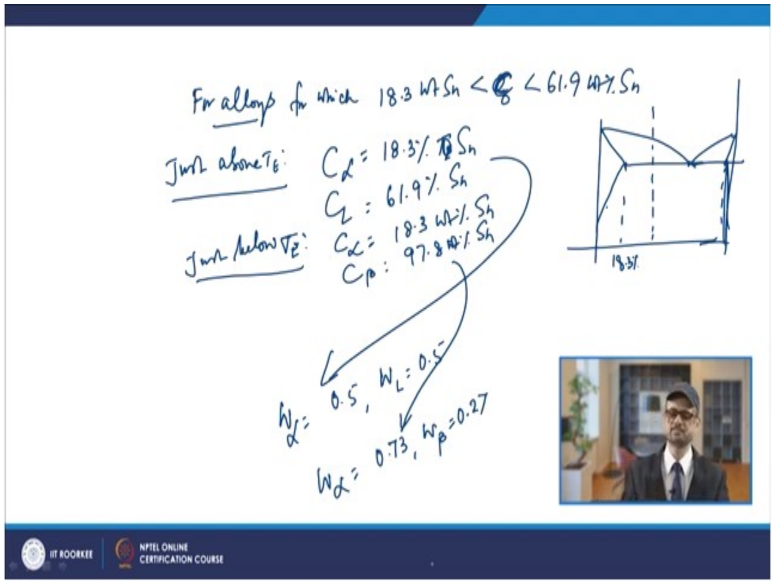


Which is having eutectic systems so what we have seen that in the case of Pb-Sn you will have you know you are goes like this so you will have you know α here and then it will be you know going like this. So this is your liquid + α and this is your liquid + . You have β here and this side you have α + .

So if you talk about the eutectic composition in this case the eutectic solidification when it occurs so microstructural development will be basically normally you will have alternate layers. So for the you know for alloy composition C_0 as C_E so when it is this is a C_E so that is your eutectic composition. So if your alloy is of this composition in that case you will have eutectic type of microstructure and there you will have you know alternate layers will be there of α and β .

So you will have alternate layers of α and β that is you know formed in the case of you know eutectic composition. Now if you take you know a composition which is from here to here. **(Refer Slide Time: 22:25)**



So if you take say the for alloys which have you know for which you have the tin percentage that is 18.3 wt% tin and C_0 is basically. So the composition will be varying between 18 to 61.9 wt% of tin. So in that case you know again your if you look at so your so this is your 61.9% and if you are talking about some composition which is there in between. Now in this case what will happen your you know just if you talk about just above the equilibrium temperature.

So in that case what happens you will have you know C_α that will be coming as18.3% you know T_E so that is tin so 18.3%. So if you talk about just above the temperature you will have the solid composition as the 18 point this is your 18.3%. So this is so if you talk about just above this line you will have the composition of the solid phase as 18.3% and just above this line the liquid each is there.

So you will have liquid and it will have 61.9% wt% tin so this is the one. If you come just below this line so if you go to just below you know TE. Now in that case you have the phases alpha and beta. So C alpha is again same so C alpha will be your 18.3 wt% tin whereas you will have the formation of beta now because below the you have this solidification. So the C beta will be again so here basically your line comes like this so this is basically you know 97.8.

So C_β will be 97.8 wt% you know tin. Now in in both the cases you will have if you calculate the W_α and W_L or in this case W_α or W_β that will can be computed and if you try to compute this so in this case if you try to find the W_α, so W_α will be in this case it will be you know 0.5 and if you find the so W_L that will be basically 0.5 so just above the you know T_E.

And similarly if you go to this case you will have W_α that is 0.73 and W_β it will be 0.27. So accordingly you can find you know how these microstructures will be changing. So that just above that you have liquid and that liquid now so ultimately you will have the conversion from so your composition and this way and accordingly the you know fractional volume which is formed that can be seen using this phase diagram you can calculate these values.

Similarly you will have the hypoeutectic case as well as the hypereutectic cases in which you calculate these you know values of these compositions and accordingly you can also calculate the weights of such cases. Now apart from that many at times you will see that you also come across certain phase diagrams where you will have the intermetallic compounds coming into picture.

Now this will be normally if you look at the phase diagram for even the you know iron carbon system. There also we are not taking carbon as the one which is so you are not having the carbon towards other side. It is basically the iron carbide that is Fe_3C. So Fe_3C basically so you get you know you get that as the intermetallic compound you are getting one the intermetallic compound that will be a line on the diagram and that also is seen in many cases.

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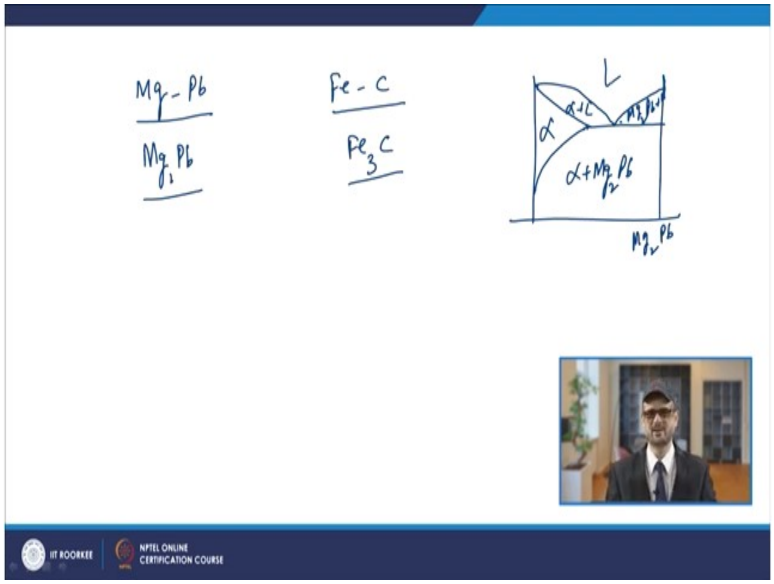

And it is normally seen that even the Mg-Pb diagram you know in that case you will have the intermetallic compound formed that is Mg_2Pb. So similarly if you look at the iron carbon diagram here also so in this case the intermetallic form will be Mg2Pb. Similarly the iron carbon diagram you get the Fe_3C. So in such cases you know you have the you will see that these inter-metallics which are formed and they become you know that they become you know one side they will be defining.

So suppose at this point in the case of you know if you try to see the you know Mg-Pb diagram what you see that you will have you know such kind of phase diagram and then it will go further and from here you will have this way so and then it will move. So here basically you are getting this Mg_2Pb. And this Mg_2Pb so you are basically you are this vertical line basically will define on this side you will have you know , α + liquid.

Similarly, you have you have α + Mg_2P. So basically you are all the phases which are taken as standard one from this side suppose in the case of copper and zinc you take copper and zinc on left and right-hand side whereas when you have intermetallic compound formation on the right-hand side you have this as the standard line and your this is becomes a phase. So that will be taken into account.

Now in this case you will have this will be Mg_2Pb + liquid will be coming and this is your liquid line. So in such cases you can have the calculation of the amount of these you know intermetallic compounds also. So then as we discussed that when we deal with other kind of you know phase diagrams like copper and aluminium. Now in those cases you will have one α solution and then that your solubility will be increased of aluminium in the copper maybe up to a certain amount.

And then you know of copper into the aluminium and then when the temperature is you know it is solidified so at high temperature it is basically its solubility limit is higher and when the temperature becomes less then slowly it will try to diffuse out. So you will have θ' phase you know that stage is there. So according to that you will have precipitates coming out and that is the concept of even precipitation hardening.

So that also is clear you know so based on that you have a precipitation hardenable alloys you can basically identify by looking at the phase diagrams that which of the materials are basically the precipitation hardenable noise where you know depending upon that formation of the you know rich you know super rich solutions which you get you can come to the conclusion that these are the precipitation hardenable alloys.

And they can be hardened by the mechanism of precipitation hardening. So this is all about the phase diagrams for the non-ferrous materials. You have many systems for which you can refer to the phase diagrams and that will be utilized for our subsequent lectures when we interact with the materials and it is you know characteristics. Thank you very much.