Welding Metallurgy
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Lecture - 10
Problem Solving on Phase Diagrams

Welcome to the lecture on Problem Solving on Phase Diagrams. So in this lecture we are going to have the problem solving session mainly based on the problems related to phase diagrams and also we will discuss about some problems one or more problem related to the Schaeffler or Delong diagram so which we could not do during the lecture classes. So coming to the, you know, questions.

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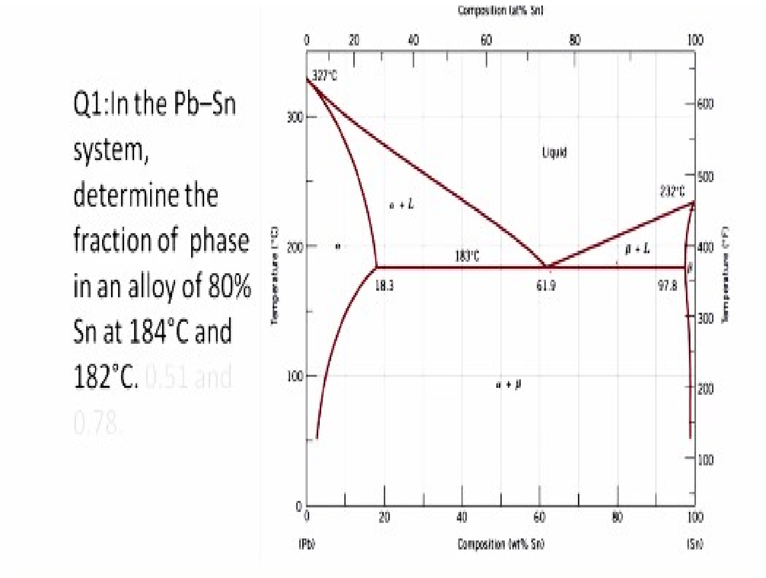

So first question is that in the Pb-Sn system determine the fraction of phase in an alloy of 80% tin at 184 ^{0}C and 182 ^{0}C . So that is you know the question and you have to solve this question. So the temperature as you see this is the Pb-Sn diagram and as you know that your eutectic this is temperature that is 183 ^{0}C. So you have to find you know for this 80% Sn composition you have to find just above this eutectic temperature and just below this temperature so what will be the you know fraction of phase in the alloy?

So as you can see that 80% is coming into this zone and once you go to this zone then in this zone is **β**+ liquid and if you are coming to temperature just below 183 that is 182 ^{0}C then you have the **α** on this side and you have **β** on this side. So basically in one case you are getting

β+ liquid and in another case you are getting **β**+ **α**. So you have to find the you know fraction of phase **β** in the alloy.

So basically that phase will be **β** only. So we are going to have the calculation for the fraction of phase **β**. Now coming to the you know temperature at 184 ^{0}C so this will be the point and for getting **β** as you know that you will have a line just above 183. So for **β** so this side is **β** so amount of **β** will be you know this distance divided by the whole distance.

So this is 80% so this distance will be 80-61.9 and the whole distance will be this is 97.8 so 97.8-61.9.

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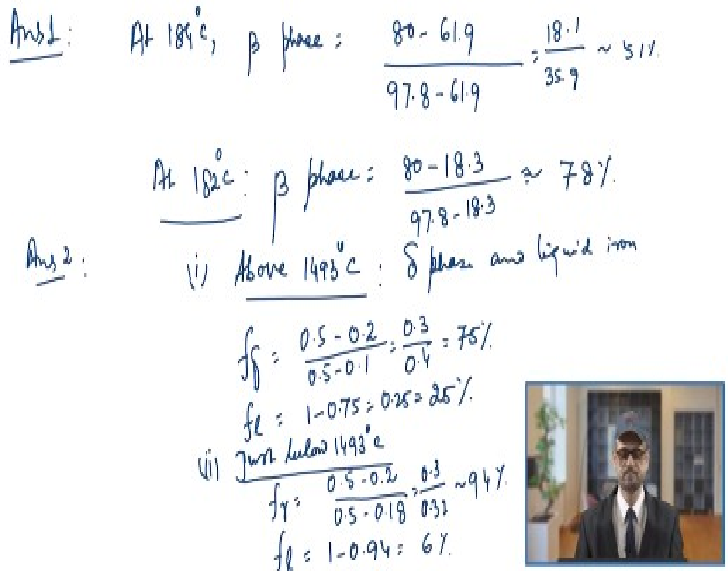

So if you see the answer of question one. So the at 184 ^{0}C the **β** phase will be so as you see that we discussed that it will be you know 80-61.9 which is the eutectic point divided by it is touching on the another side on the right hand side at 97.8. So you will have 97.8-61.9. So we are using this lever rule and it will be 18.1/35.9, so it will be coming close to 51%.

So that is what you are seeing you know in this case it will be coming as 51%. Now if you go to the temperature just below this temperature just below 183 ^{0}C. Now here you will have to if you draw the Tie line rule so it will be touching one is **β** point another is this is the **α** for this **α**. So **β** phase it will be formed **β** so its amount will be according to lever rule this ratio divided by the whole ratio.

So this ratio will be this is 80 and this is 18.3 so the **β** phase will be 80-18.3 divided by the total you know distance that is 97.8-18.3. So at 182 ^{0}C the **β** phase will be so as you know **β** is on this side so as per liver rule we will go towards left so it will be $(80-18.3)/(97.8-18.3)$. So it will be approximately you know 78% so that is what you see in this case.

So this will be this distance divided by whole distance so it will be coming close to you know 78%. So it will be you know 61.7/79.5 so it will be approximately 78%. So that is how you can calculate the amount of phase and if you go to 182 ^{0}C rest percentage will be the **α** phase so you will have **α** as 22% around. So that is how you calculate the value of the **β** phase. Coming to the next question.

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Q2:From the Fe–Fe_3C phase diagram, for a 0.2% C steel, name the phases and their fractions at equilibrium at the following temperatures:

- (i) just above 1493°C, (ii) just below 1493°C,(iii) just above 725°C, and(iv) just below 725°C.

Q3:What is the fraction of proeutectoid cementite in (i) 1.4% C, (ii) 1.0% C, and (iii) 0.7% C steels?

Now the next question is from the iron carbide phase diagram for a 0.2% carbon steel name the phases and their fractions at equilibrium at the following temperatures. So now we have to find the different phases and also their fractions at equilibrium so we have the different temperatures given just above 1493.

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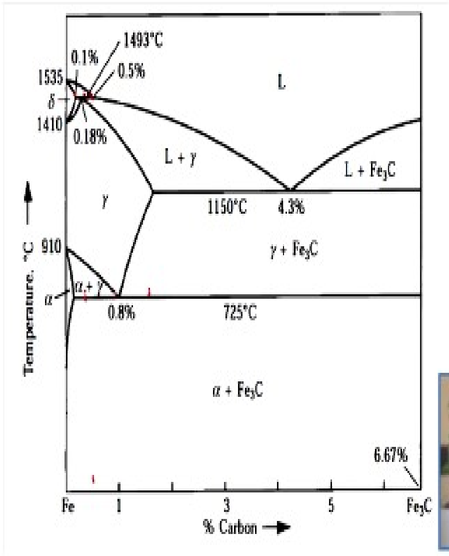

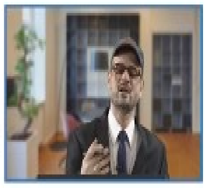

So we have to see the iron carbide diagram. Now this temperature is the 1493 ^{0}C and we are talking about the composition that is 0.2% carbon steel so this is 0.18 so you will have 0.2 here and for 0.2 and just above this it is going into this zone. This zone is you know this is δ+ liquid so this side it is liquid so you will have you know δ as well as liquid.

Now on this point if you draw the line on one side it will be touching this point and on another side it will be touching this point. So for finding and this is the δ phase so amount of δ phase will be proportional to so that will be its fraction will be this distance divided by the whole distance. So you have you know 0.2% of steel and on this side it is given as it is 0.5 So the percentage of δ phase will be $(0.5-0.2)/(0.5-0.1)$.

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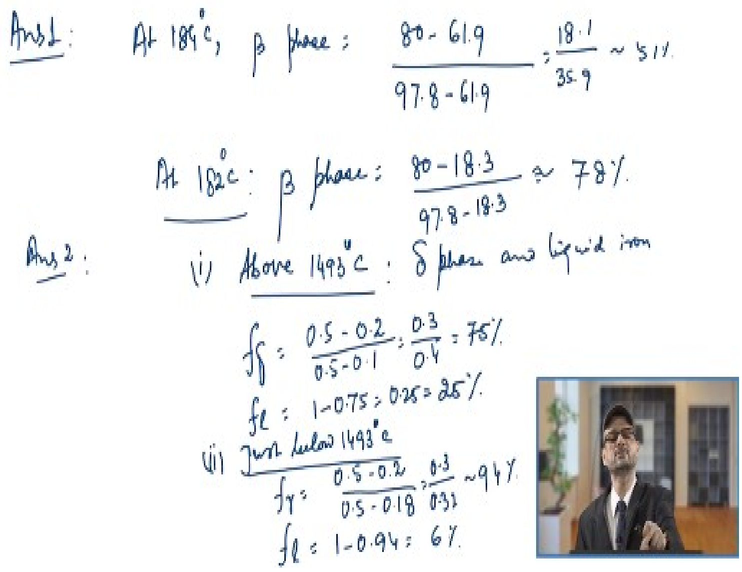

So if you go to answer for question 2 then for first above 1493 ^{0}C. You have two phases one is δ iron δ phase so δ iron and another is liquid, liquid iron. Now for δ as you see that δ is towards left so using the lever rule you have to see towards the right where it is touching that liquidus line. So it is just above that temperature line it is at 0.5.

So the fraction of δ I mean δ phase it will be you know so you will have 0.5 towards the rightmost point and we are talking about 0.2% and ultimately it is going towards 0.1% towards the extreme left so it will be 0.5-0.1. So it will be $0.3/0.4$ so it is 75%. So you have 75% of the δ ferrite phase is formed just above 1493 ^{0}C of temperature. So above the 1493 if you view that the next phase is that one is liquid so liquid will be 1-0.75 so it will be 0.25, so 25% will be the liquid phase.

Now we have to see the next is that just below 1493 ^{0}C so if you come to just below 1493 ^{0}C. Okay so let us see how you know about what is the phase. So just below so we are talking about a point which is so this is 0.18 so this will be 0.2 and just below that it is going into this liquid+ γ zone. Now in this liquid +γ zone if you draw a tie line it will be touching somewhere close to this on this side and another point will be just here that is 0.18%.

So you will have one side is for the γ another side is for this liquidus line. So you have the formation of γ phase as well as the liquid so you have to find γ. Now for γ since γ is on this boundary. So the γ percentage will be for the distance from 0.2% to 0.5% and that will be respective to 0.5-0.18. So if you try to find the fraction of γ it will be $(0.5-0.2)/(0.5-0.18)$it is. So it will be $0.3/0.32$ so it is coming close to 94%.

Okay so that is how you are getting the fraction of γ. So if you take the next phase that is liquid only. So the liquid fraction will be the rest one that is 1-0.94 so it will be 6%. So just below the 1493 ^{0}C you have the 94% of γ and 6% of liquid. So next is so in this question only then you have to find just above 725 and just below 725. So if you go to above 725 and that to for 0.2% you know carbon.

So if you go above 725 now in this case you are getting **α** + γ and if you go you know just below 725 then in the below 725 you are getting **α** this side and this side you have Fe_3C line. So above you know 725 you are getting **α**+ γ below 725 you are getting **α** + Fe_3C. Now percentage of ferrite for above 725 so if suppose you have the you know 0.2% line somewhere so just above that.

So for **α** you have to have this line and divided by the whole length so from here to this point. So you are getting something like 0.8-0.2 and this point is normally point 0 2% so $(0.8-0.2)/(0.8-0.02)$.

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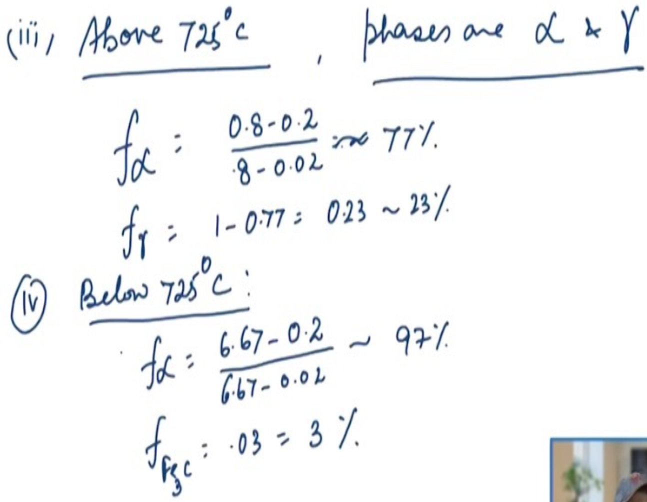

So if you go you know for third part if you go above 725 ^{0}C you have phases are **α** and γ now **α** fraction of **α** will be the using the lever rule it will be the fraction of the right-hand part. So it will be $(0.8-0.2)/(0.8-0.02)$ so it is coming you know close to you know 70 so it will be close to 77%. So rest will be your γ and f_{γ} will be 1-0.77 that will be 0.23 so it will be 23% that even can be calculated because if you want to calculate the γ and γ is on the right hand side.

So γ will be $(0.2-0.02)/(0.8-0.2)$ like that so that way you will get this value only 23%. Now if you come to the temperature below 725 so below 725 ^{0}C as we discussed we have two phases one is **α** another is Fe_3C. So for **α** you have to take the you know distance from that 0.02 to 6.67. So f **α** will be 6.67-0.2 because the **α** will be corresponding to this line divided by the whole line.

So (6.67-0.2)/(6.67- 0.02). So if you take this value it will be close to 97% so rest will be Fe_3C and Fe_3C as you see if it is 97% then it will be 0.03 that is 3%. So this way you can calculate the values of these different phases. Now next question will be you will have the next question and that question is that what is the fraction of pro-eutectoid cementite in 1.4% carbon?

Now we are talking about the formation of pro-eutectoid cementite in 1.4% carbon. So this is your about 1.4% carbon so this will be somewhere here this is 0.1 maybe somewhere here. Now what will be so pro-eutectoid cementite, cementite which is formed before this eutectoid reaction what will be that? So cementite will be corresponding to this length divided by this whole length because cementite is touching you know on this side this is the cementite line.

So it will be corresponding to this line divided by the whole line so it will be $(1.4-0.8)/(6.67-0.8)$.

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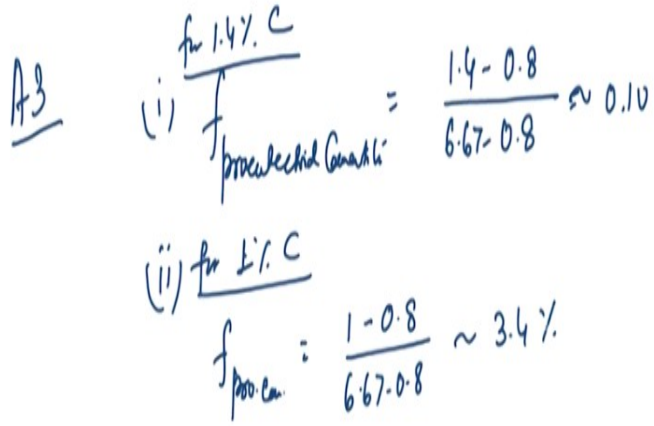

So if you go to question answer 3 and pro-eutectoid cementite so if you take the first part pro-eutectoid cementite, eutectoid cementite it will be for 1.4% so as we discussed it will be $(1.4-0.8)/(6.67-0.8)$. So it will be something very much near to 0.10 so about 10% of pro-eutectoid cementite you will be getting in this case when you have 1.4% of carbon.

Now next is you have 1% carbon. So for 1% carbon when you are coming again here on this line so for 1% carbon again it will be $(1-0.8)/(6.67-0.8)$. So it will be again we have to calculate. So for 1% carbon so this is for 1.4% carbon and this is for 1% carbon for 1% carbon $f_{\text{pro-cementite cementite}}$ will be $(1-0.8)/(6.67-0.8)$.

So it will be coming close to 3.4%. So if you do the calculation you will get it close to this value of 3.4%. Now the next question is next part of this question is 0.7% carbon steel so if you are coming to 0.7% carbon steel it is you know below this so it is below this line and in that case you know that cementite it is touching simply here this line. So in that case it will be 0.

So basically what you see that so that is why this is not coming into picture. So basically your value you know in that case will be negligible it will be 0. So this is how using the different type of phase diagrams you can you know calculate the fractional amount of the different phases using the phase diagrams. Now we will have the discussion about the use of the Delong diagram.

So in our earlier lecture we discussed about Schaeffler diagram where from that diagram we try to find the weld metal deposit concentration you know composition and apart from that we also discussed about the Delong diagram where basically the you know especially for the presence of nitrogen you know when you have to analyze then the Delong diagram is used.

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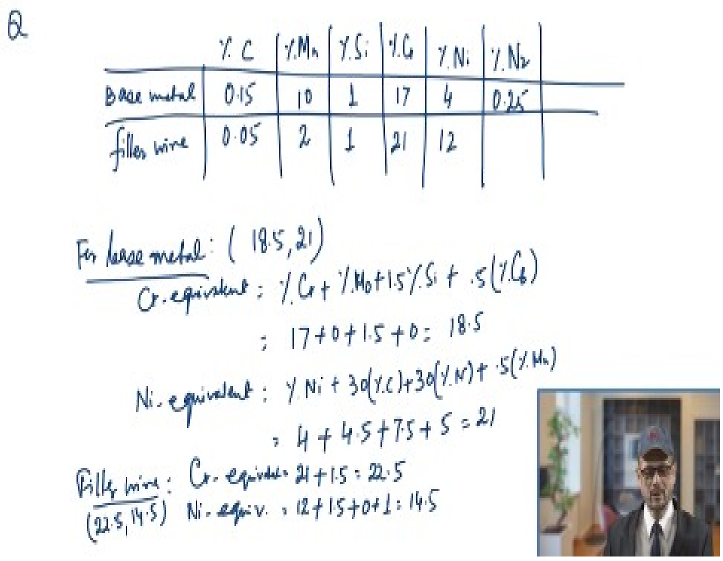

So let us say there is a problem and problem is that you have you know the stainless steel is you know wire stainless steel that is to be welded and it is to be welded using a wire also that is also stainless steel grades. So you have two different grades of stainless steel one is for the you know base material another is for the wire. So for base metal and for the filler wire the different you know composition is provided.

And different composition is in the terms of % carbon, % manganese, % silicon and you know % chromium, %centage nickel and % nitrogen is given. So as you know that in the case of when the nitrogen is present we will use the Delong diagram and for base metal and also for the you know filler wire the composition is like for base metal is 1.5 and filler wire it is 0 05.

For the base metal manganese is 10 and this is 2 similarly you have 1% silicon in both the cases, chromium is 17% for base metal and 21% for the you know filler wire and nickel is 4% for base metal and 12% for the filler wire and this is 0.25% in the base metal. So what you have to do is you have to find the maximum and minimum amount of the ferrite phase which is possible in the weld metal so that you have to calculate.

Now for that you need to look into the Delong diagram and this is the Delong diagram which is given this Delong diagram again here you say we see that this is the chromium equivalent which is calculated using this formula chromium + molybdenum you know % molybdenum you know and then you have these values are given + 1.5 times % silicon+ 0.5% columbium.

And similarly you have nickel equivalent value also given and that can be from here you will get the nickel equivalent and from there you will get these two points. So first of all we will be finding the chrome equivalent and the nickel equivalent values. So if you try to find the you know for base metal for base metal and for the filler wire also. So for base metal if you find the chrome equivalent.

So chrome equivalent will be you know as you know that it is % chromium + % molybdenum + 1.5% silicon + 0.5% columbium. So that way so percentage chromium is as you see it is 17 % molybdenum is anyway not there. So then you have 1.5% silicon so it will be 1.5 and columbium again is not there so you will have 17 + 1.5 that is 18.5.

Similarly, if you find the nickel equivalent for the base metal so nickel equivalent for the base metal will be again for the formula % nickel + 30% carbon +30% nitrogen and 0.5% manganese so that is the formula for the nickel equivalent. So nickel as you see nickel is 12% for this case no nickel is 4% for the base metal so 4 and carbon is 0.15 so 30 times 0.15 it will be 4.5.

So it will be 4.5+ 30 times % nitrogen, nitrogen is 0.25 so it will be 7.5 and then you have 0.5% manganese, manganese is 10% so it will be 5. So it will be coming to 21. So for the base metal you are getting the point you know on the Delong diagram that is your 18.5 and it is 21. Now similar way we are going to calculate for the filler wire and for the filler wire we are going to have the calculation for chrome equivalent.

And for chrome equivalent we are going to get again % chromium so chromium is 21 then you have % molybdenum so molybdenum anyway not there then 1.5% silicon, silicon is in both the cases it is same and + 0.5% columbium so it is anyway not there so it is 22.5 and if you calculate the nickel equivalent so nickel equivalent will be % nickel, % nickel in this case it is 12.

And then you have 30% carbon. Carbon in this case it is 0.05 so 30 ×0.05 that will be 1.5 then you have 30% nitrogen, 30% of nitrogen so nitrogen is anywhere not there so it will be 0 and further you have 0.5% manganese, manganese is 2% so 0.5 × 1 so it will be 14.5. So for filler wire the point which you are getting it is 21 14.5 so it is 22.5 and 14.5 so your point is 22.5 and 14.5.

Now you can have to basically put these two points on the Delong diagram so you have two points that is 18.5 and 21 and next is you have 22.5 and then you have 14.5.

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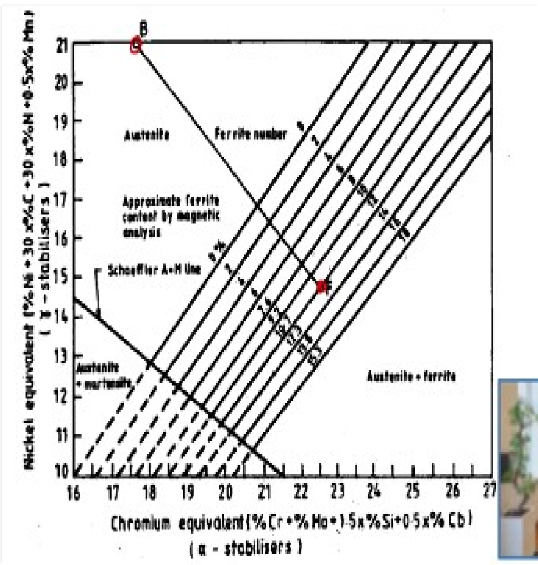

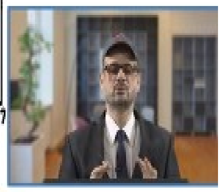

So 18.5 21 if you go so 18.5 and 21 it goes to this point and the next point is 22.5 so that will be here and then further you go to 14.5 so it is coming to this point. Now what you see these

are your ferrite numbers which talks about 0%, 2%, 4% up to 18% of ferrite and in that case. So ferrite number this is represented by this line and you are having this point here. So what you see that you have you know this side is a ferrite you know %age this is the ferrite %.

So we are talking about these 10.7 so we are getting this 10.7 so this 10.7 is the maximum ferrite which is available so this is for the base metal and this is for the filler wire. So from this question what you see that you have a minimum of the ferrite content what you get is you know 0% and maximum of the ferrite which you are getting so that is basically maximum of ferrite phase is 10.7%. So that is you know clear by the use of this Delong diagram.

So this is how you are going to use you know so we have already seen the use of the Schaeffler diagram and then this is how the Delong diagram where the nitrogen is there so in that case we can use this Delong diagram.

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Q4:Calculate the fraction of proeutectoid ferrite, eutectoid ferrite and total ferrite in a 0.2% C steel.

So next we have we may have another question like calculate the fraction of pro-eutectoid ferrite, eutectoid ferrite and total ferrite in a 0.2% carbon steel. So if you talk about the 0.2% carbon steel you know you go to this iron carbon diagram and for the 0.2% carbon steel if you are coming to again this point or so. Now at this point if you have to find the pro-eutectoid ferrite formation.

So pro eutectoid ferrite will be you know you will have means before this reaction so before this eutectoid reaction you have to find the pro-eutectoid ferrite fraction. So this line is for the eutectoid reaction. So pr-eutectoid ferrite that is ferrite which is for before this eutectoid reaction. So this will be corresponding to this line divided by the whole line. So it will be you know (0.8-0.2)/(0.8-this point).

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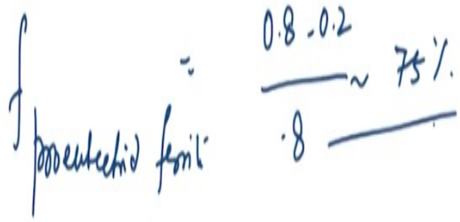

So roughly if you try to calculate that point it will be you know $f_{\text{pro-eutectoid ferrite}}$ so it will be you know 0.8- 0.2 because a 0.8 is on this line so ferrite line is this so you are getting 0.8- 0.2 and then you have to have this you know $(0.8-0.02)/0.8$ so it will be coming close to 75%. So this way you will get the pro-eutectoid ferrite you know formation.

Similarly, now you know so you can calculate the eutectoid ferrite you can get calculate the total you know ferrite total ferrite means when after the eutectoid reaction basically you are you know getting the ferrite as well as the cementite. So after the eutectoid reaction so you have that is the ferrite+ cementite coming up so altogether you will have the total cementite.

So if you calculate the eutectoid ferrite it will be coming as you know about 0.22% if you calculate the eutectoid ferrite % that will be 0.22. So if you sum them all together it will be 0.75+ 0.22 so it will be 0.97 so 97% will be total ferrite. So this way you know you can calculate so you will have eutectoid total ferrite calculation you will have pro-eutectoid ferrite calculation and accordingly you can you know find the you know total ferrite that will be the 97%.

So these are the different type of question you can practice on more and more questions and you can have you know more confidence when you deal with more questions you know for getting you know by using the different types of phase diagrams and that will help us later in our course. Thank you very much.