Steel Quality Role of Secondary Refining and Continuous Casting

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Module - 05
Lecture - 27
Role of Chemistry: Part II

Let us go to stainless steel as I was telling.

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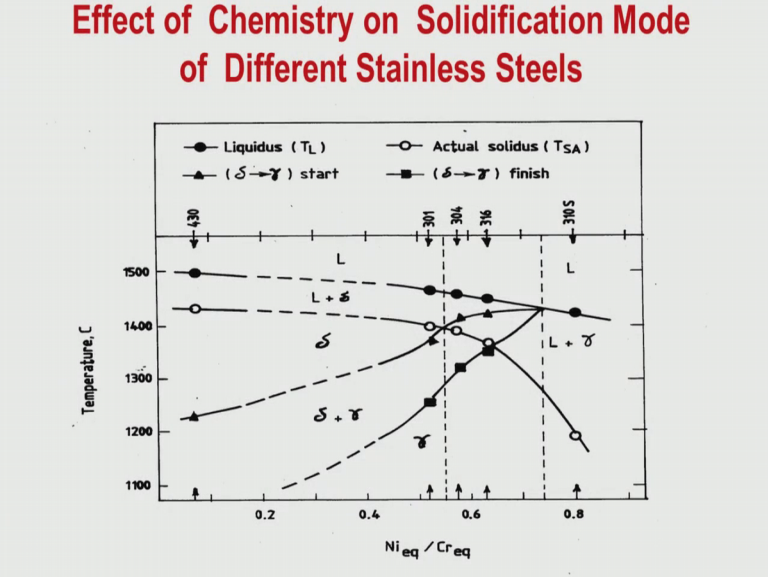

Stainless steel has so much of chromium and sometimes nickel that normal iron carbon diagram cannot explain how the solidification will take place. So, what is important is to draw another diagram which will indicate what are the different delta and gamma for different chemistry stainless steel.

So, now I have shown here different stainless steels you know 430, it is a ferritive grade hardly in a nickel mostly chromium grade. 301 is as you are going this side means look what is happening. Nickel equivalent by chromium equivalent is this; this you know horizontal axis. In iron carbon diagram it was carbon or carbon equivalent, here it is nickel equivalent by chromium equivalent. That means, from these diagram all stainless steels can be represented in this diagram.

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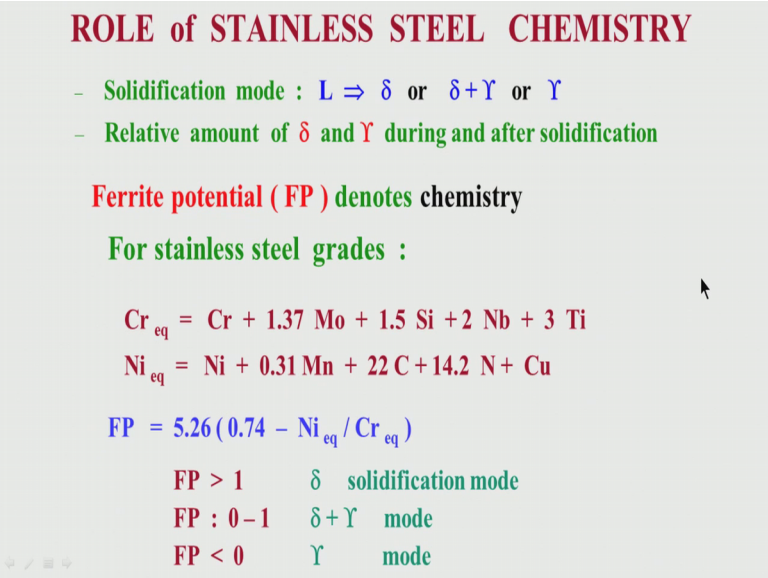

How? By calculating what is the nickel equivalent by chromium equivalent. I will show in this figure how nickel equivalent, chromium equivalent are found out. Chromium equivalent means, chromium is basically ferrite stabilization. So, whatever alloying elements which stabilize ferrite they will go to chromium equivalent calculate. See chromium actual chromium plus the given factors are there 1.37 mole 1.5 silicon 2 niobium 3 titanium.

So, these are all stabilizing ferrite and stabilizing chromium, so increasing chromium equivalent. But look at another elements; manganese, carbon, nitrogen, along with nickel of course, copper, these are all austenite stabilizer. So, they increase the nickel equivalent.

So, this since chromium and nickel are the two important alloying elements for stainless steel what has been done is- all the alloying elements have been divided into two broad categories. Whether there is ferrite stabilizer then they have put together for finding out the chromium equivalent. If they are austenite stabilizers then they are been put together along with nickel, because nickel is a austenite stabilizer and chromium is the ferrite stabilizer.

So, how solidification will take place through ferrite; that means, delta or through austenite? So, in iron carbon diagram it was everything by carbon or carbon equivalent, here we have to look in to the two alloying elements: chromium and nickel. And not just

chromium nickel, the chromium equivalent or nickel equivalent, because chromium stabilizes ferrite, nickel stabilizes austenite.

So, how the alloying elements are stabilizing ferrite or austenite; if you understand that we have determined; what is chromium equivalent, what is nickel equivalent. So, for any stainless steel we can calculate what is chromium equivalent, what is nickel equivalent and we can calculate; what is the ratio of nickel equivalent by chromium equivalent? That is what we have shown in this figure.

So, this nickel equivalent by chromium equivalent we are plotted along this horizontal axis, this is the temperature. So, all the popular grades I have put for 30 is a ferritive grade standard steel grade 301 almost austenitic grades 304 we are increasing austenite 310 s- totally austenite grades.

So, now like iron carbon diagrams what was happening less than 0.1 percent carbon it was totally ferritic. Here what is happening less than point; this is 0.5 so this is 0.55; less than 0.55 nickel equivalent by chromium equivalent only delta. So, we have initially liquid the liquid plus delta then delta. So, solidification is complete only through delta for nickel equivalent by chromium equivalent less than 0.55.

If we have nickel equivalent by chromium equivalent more than 0.55 look at this particular grade of stainless steel 310s, is very much austenite. Only austenite solidification is taking place. Liquid that is going to liquid plus gamma then finally gamma. So, like you know percentage carbon indicating; what is the mode of solidification here, nickel equivalent by chromium equivalent is indicating; what is the mode of solidification, what is the solidificational sequence? For lower nickel equivalent by chromium equivalent only through delta solidification is taking place, only after deltas form that means solidification is complete then only gamma is coming here.

In between 0.552 to point this is 0.55 and this is 0.7; so 0.75. So, in 0.74 actually, this is valid. So, this range indicates delta plus gamma and beyond this gamma. So, like iron carbon this portion is only delta solidification, this portion is that means high nickel equivalent chromium equivalent very high only gamma in between delta plus gamma. Look at 304 what is happening?

Initially liquid then liquid plus delta then delta plus delta to gamma this is the delta gamma you know liquid delta gamma. So, it is delta to gamma is taking place almost near solidification completes. So, as I mentioned you when this delta to gamma solidification is taking place is very important.

Look at 301 solidification is complete through delta and delta to gamma is taking place after solidification 304 delta to gamma is taking place just before solidification 316 delta to gamma is taking place much ever up complication of solidification, yes, yes, say around say 0.3 percent of solid fraction; that means, during solidification and towards the almost was the beginning of solidification 363 10s no delta at all solidification only through gamma.

So, these are all very important information for understanding what is the sequence of solidification is it the solidification taking place only through delta only through gamma or delta plus gamma; if it is between delta plus gamma then when delta to gamma is taking place during solidification like 304; you see delta to gamma is starting here and solidification is complete here. So, before solidification or towards the end of solidification delta to gamma is taking place.

301 solidification is complete no gamma formation has started only just below the solidification you have delta to gamma transformation solid state transformation 430 totally ferritive grade liquid to delta only. Delta solidification is complete here; gamma is taking place quiet, you know below the solidification; solidification is complete here. So, gamma is taking place only at around say 1200 degree centimetre solidification is complete at say more than 1400 degree centimetre.

So, 301 solidification is complete as around say 1400 and then gamma is taking place just beyond may be 20 degree below this just delta to gamma is taking place. So, even if delta to gamma is taking place in during the solid state where it is taking place is important. So, whether it is within solidification range then at what stage of solidification like 304 delta to gamma taking place towards the end of solidification.

316; I mean at much higher region of solidification. So, solid fraction will be say around say 0.3 here, here solid fraction is may be 0.755 0.8 here or may be 0.8; 0.85. So, delta to gamma transformation where does it take place is very important why again and again I am repeating because delta to gamma generates lot of strength. So, that strength is going

to create some problem during solidification. So, that is why where it is taking place is important at what stage of solidification is taking place or whether it is taking place in solid state these are all important.

So, as I was telling in standard steel unlike r n carbon or in a plane carbon steel or low alloy steel carbon equivalent there carbon equivalent can determined you know the mode of solidification here the ratio of nickel equivalent by chromium equivalent determines the mode of solidification. So, we are finding out chromium equivalent depending on what are the alloying element is present. We are finding how nickel equivalent; what are the alloying element is present 430 grade that was having quiet smaller amount of nickel. So, the nickel equivalent chromium equivalent was quiet low. So, if it is quiet low then what is going to happen if I write potential will be very much positive. So, it is delta solidification look at this figure.

Here 0.74 is this particular chemistry. So, beyond 0.74 it is only gamma solidification if you have a nickel equivalent per chromium equivalent say 0.75, let us say then what is happening 0.7 for minus 0.75 that is minus into 0.5; 0.26, thus the whole thing is negative. So, ferrite potential is less than 0; that means it is gamma mode.

So, if nickel equivalent chromium equivalent is same if you look at this figure. So, less than this figure 0.55 then what happens if you multiply 5.26 into 0.74 this figure. This is basically this is the figure; that means, when you are going to a particular nickel chromium equivalent which is less than this figure 0.55. So, then your solidification is totally delta.

So, this equation indicates suppose you have a say 0.74 minus 0.55 how much it become 0.19 then you multiply it with 5.26. It becomes one that is why the significance of 0.74 is that because 0.55 if you deduct 0.55 with the nickel equivalent chromium equivalent this basically the ratio if you divide with this and then multiply with this. So, basically it will give one so; that means, delta solidification means more than 1.

So, please try to remember from this figure; what I have told is whenever nickel equivalent by chromium equivalent ratio is more than 0.55 you have delta solidification if it is more than 0.74. It has only gamma solidification when this ratio is in between 0.55 to 0.74. It is delta plus gamma, but this relative when delta to gamma will take place will depends on this as you are increasing nickel equivalent chromium equivalent value delta

to gamma is taking place at earlier temperature you know during solidification; this is what is important.

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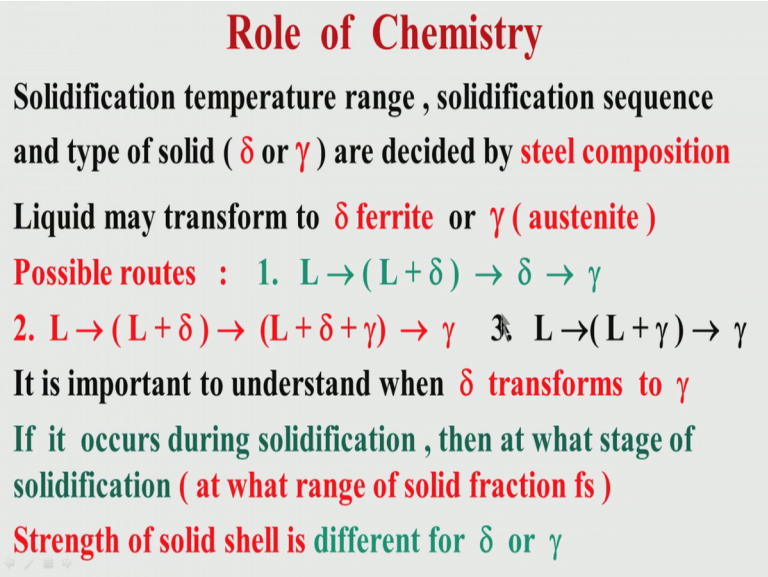

So, I have try to explain the role of chemistry; that means, basically what is the solidification temperature range; how the solidification sequence will change with chemistry; what are the type of solids delta and gamma during solidification and even beyond solidification; what then solidification also this relative proportions may change the chemistry will dictate how the solidification is taking place and what are the relative proportion during and at temperatures lower than solidification.

So, there are 3 possible roots liquid going to liquid plus delta then delta and then gamma. So, this is the situation for carbon less than 0.1 then another may be liquid going to liquid plus delta then liquid plus delta plus gamma then gamma. This is the situation for a carbon content between 0.1 to 0.5. Another sequence may be liquid going to liquid plus austenite and then austenite only you look finally, everything is austenite then you are coming to low temperature may be around 1000 or 1200, but how it is coming what are the sequence that is change in depending on your chemistry.

As I have told for iron carbon it is the carbon or carbon equivalent for liquid standard steel it is ratio of nickel equivalent by chromium equivalent. So, that factor; that means, the chemistry will dictate carbon equivalent for plane carbon and low alloy steels and for

stainless steels nickel equivalent by chromium equivalent this ratio will determine the chemistry specific chemistry and we will dictate how the solidification takes place.

So, again I am repeating it is important to understand when delta transforms to gamma as I was telling you looking at you know different figures it if it occurs during solidification then at what stage of solidification as I was giving examples of solid fraction of at what solid fraction all the stage of solidification later part or still lower temperature then after solidification is complete, when does it take place and I mentioned why all these are important because delta and gamma strength of solid shell is different.

So, whatever solid shell is forming it has a defined strain depending on whether you have delta or gamma also I will come to it later on. It will also indicate the segregation is also not equal for delta and gamma all of us know the segregation will take place between solid and liquid, but what is the solid that will dictate what is the extent of solidification what is the solute that will dictate what is the extent of solidification or you know what is the extent of segregation.

So, delta and gamma sequence of solidification which is delta; delta plus gamma or gamma whether it is delta ferrite or austenite or mix mode is important from many factors first the strength of the solid shell, because it is different from delta to gamma second segregation. It is also different extent of segregation is different if solidification is to delta or solidification to gamma and also it is delta to gamma when it takes place this important because it generates some stress some strain some contraction because of it contracts in volume.

So, that strain will be incorporated. So, at what stage is getting incorporated is important whether the shell can withstand that strain or not. So, whether during solidification and or after solidification these are all important issues.

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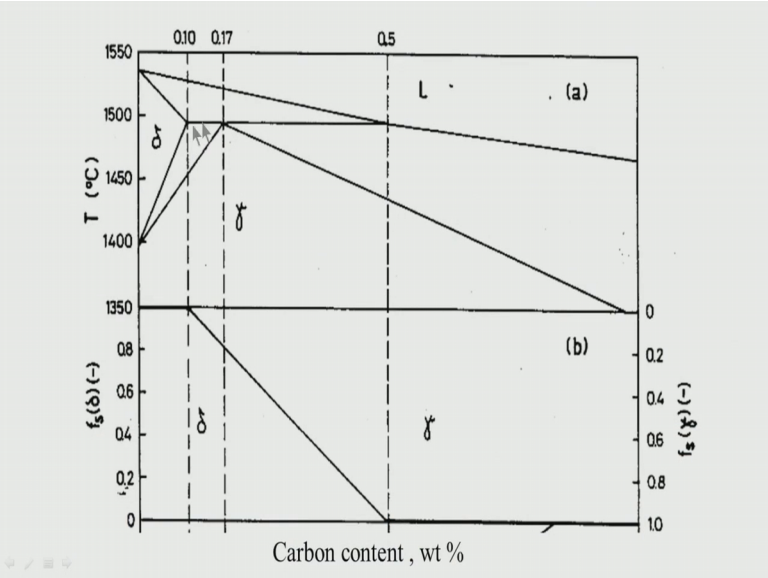

So, you see delta to gamma is taking place where if it is during solidification; that means, between this 0.1 to 0.5 percent carbon at what stage delta to gamma is taking place that is important. If it takes place here; that means, it is delta to gamma is taking place near the in tactic rather pay tactic temperature, but if it is for this you know carbon say 0.2; 0.3 then it is taking place lower than the at the lower end of the solidification. But that is important is what stage is taking place and here it is taking place delta to gamma taking place.

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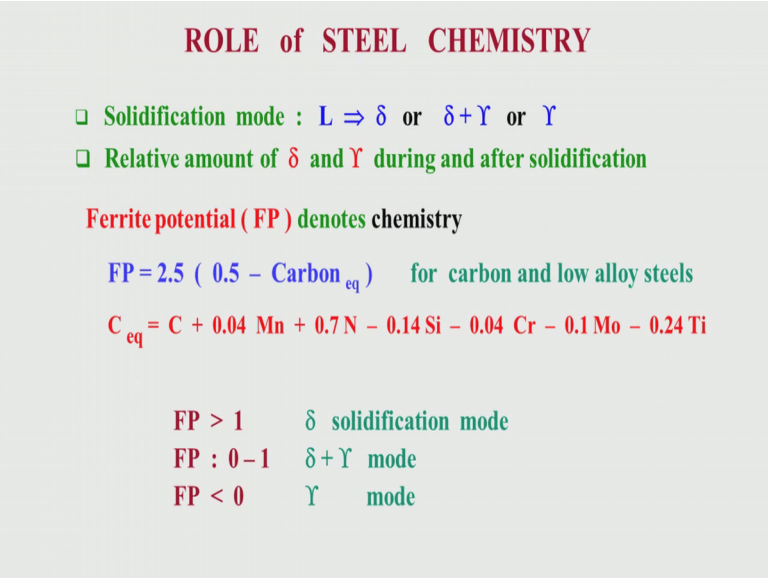

Then the solidification is complete towards the end of the; you know reaction solidification reaction is taking. So, these are important issues.

So, then I have told for you know stainless steel iron carbon diagram cannot indicate the sequence of solidification. So, you must have a different diagram where instead of carbon equivalent we have nickel this ratio nickel equivalent by chromium equivalent more the austenitic solidification means we are going to have nickel equivalent by chromium equivalent at this ratio of say 0.55 less than that it is totally delta solidification only delta ferrite beyond 0.74 it is only austenitic solidification in between 0.55 and 0.74 we have next and for different grades depending on the this ratio at what you know location the solidification takes place also is dictated.

So, for stainless steel you will find out chromium equivalent by nickel; nickel equivalent depending on the chemistry specific chemistry and from this equation we know what is the ferrite potential that indicates the ferrite potential is more more than one and it is totally delta solidification; that means, ferrite potential is less than 0.55; 0.74 minus 0.55 into 5.26 is basically this figure one you will get. So, it is more than one if it is less than 0.55. So, if it is greater than one ferrite potential delta solidification and if the ferrite potential is rather with the nickel equivalent by chromium equivalent is more than 0.74; that means, this is negative this ferrite potential if it is negative one negative is a fraction is less than 0; that means, it is a delta mode of solidification; so, less than 0. So, is negative. So, it is a delta mode of solidification.

So, more than one delta between 0 and one delta plus gamma less than 0; that means, it is negative it is gamma mode of solidification; that means, it is becoming as the ratio between nickel equivalent chromium equivalent is increasing here coming to more and more austenitic solidification that is the whole idea.

Thank you very much.