Steel Quality Role of Secondary Refining and Continuous Casting

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Module - 05
Lecture - 26
Role of Chemistry: Part I

Good morning. In the last session I have talked about the cast structure: how to have a desirable cast structure, how to have a finite dendrites, how to have relatively wide equiaxed zone. These are important issues with respect to the cast quality.

Now, another important issue I will be discussing today this is called the role of chemistry. That means the grade, whatever steel grade we are using what effect does it have on the cast quality. This is very important. So, we know the steel we can have different carbon, we can have different alloying elements. So, for plane carbon and low alloy steels the solidification will be dictated by; how the solidification will take place will dictated by to some extent to a large extent rather by the iron carbon diagram.

In iron carbon equilibrium diagram you have iron and carbon, but since in low alloy steels you have some alloying elements. So, instead of carbon it is better to understand what is carbon equivalent. Carbon equivalent means how other alloying elements like common alloying elements, like manganese, silicon, chromium, you know nickel. what I am talking is or molybdenum, I am talking is low alloy steel how they affect the activity of carbon and how the iron carbon diagram gets influenced by that.

Now, there is another category of steel like stainless steel which has very high amount of chromium and nickel. Chromium is of course always there minimum 11-12 percent chromium maximum may be 25-30 and nickel also might be there in most of the grades. So, here the amount of alloying element is very high. So, iron carbon diagram can no longer dictate how the solidification will take place is those grades.

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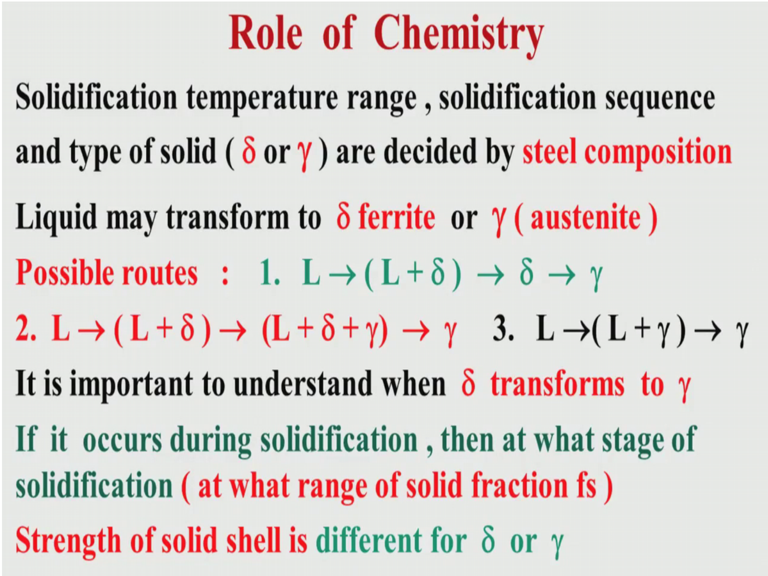

So, iron carbon diagram or pseudo iron carbon diagram we call it can indicate how the solidification will take place in plane carbon and low alloy steels. But in stainless steel we have to go for some other diagrams that will come in afterwards when I discuss stainless steel.

So, solidification temperature range and the solidification sequence; that means, what is the type of solid is it delta or gamma, they are decided by the steel composition. When you are cooling a steel from liquid to a solid I will come to the you know iron carbon diagram which will be more clear then. What is important is to understand that during depending on the carbon it can come through the delta solidification or gamma solidification or something in between. So, what are the possible roots, let us try to see.

First the solidification sequence will depend on chemistry also the solidification temperature range, because as you are going to more and more carbon or you are increasing the alloying elements you know liquidus and solidus they are changing. So, difference between liquidus and solidus which is known as the solidification range will also change depending on the chemistry. For 0.05 percent of carbon solidification temperature is something. And you when you go to 1 percent carbon solidification range is quiet big and the actual temperatures of solidus and liquidus are also relatively lower. So, what is important is- with chemistry solidification temperatures are changing, liquidous temperatures are changing, solidification temperature range is changing, solidification sequence is changing. So, these are very important to remember

Now, what are the possible roots when you change the steel composition? From liquid it can get into the liquid plus delta region then delta and then finally to austenite. Or, another root may be liquid it is going to liquid plus delta then peritectic reaction takes place, so liquid part of the liquid plus delta will generate gamma. So, finally, we are going to liquid plus plus gamma region and then gamma austenite. Or when you are going beyond the peritectic reaction what is happening; there is no delta, so liquid goes to liquid plus gamma and then gamma.

Finally at low temperature you have only gamma, but the solidification mode is different please try to remember you might tell at nine hundred degree centigrade everything is gamma of the chemistry austenite, but that is half of the story the half of the story first we should remember that how the solidification is taking place solidification is taking place when the carbon is very low you will find it is taking place with the delta region and then finally, gamma is forming.

So, when within the peritectic range; it is also taking place first delta and then going to gamma, but when this beyond the peritectic range; that means, more than 0.5 percent carbon it is only through gamma the three possibilities are there. So, it is also important to understand when this delta to gamma transformation is taking place initially as I am telling you here delta then delta then delta to gamma. So, when this delta to gamma is taking place is important that also has lot of implication on the quality of steel because that is a stress transformation; transformation stress from delta to gamma may add to the seriousness of the problem quality issues. So, we have to remember that.

So, how the transformation is taking place is important then what is the mode of transformation that is first important during solidification and then delta to gamma; that means, this is also solid, this is also solid, this delta to gamma is taking place, where is it during solidification or after solidification that is important; however, as I have mentioned if it occurs during solidification then what stage of solidification is it at the early stage of solidification medium stage of solidification or towards the end of solidification; that means, that what range of solid fraction is taking place is very important all these will be more clear when I discuss the specific issues.

And why this is important? How it is solidification is taking place? Because the strength of solid shell for delta and gamma are different it has been found delta ferrite is relatively soft and austenite I am talking about high temperature strength this is all solidification means relatively high temperature properties are important.

So, what is important is at high temperature what is the strength and toughness of solid shell delta or solid shell gamma; gamma has much has strength compare to delta. So, this is that is why how the solidification takes place will lead us to what is the strength of the shell whether it is delta or gamma if it is delta then it is soft solid shell is soft if it is gamma solid shell is relatively hard. So, these are first thing to remember.

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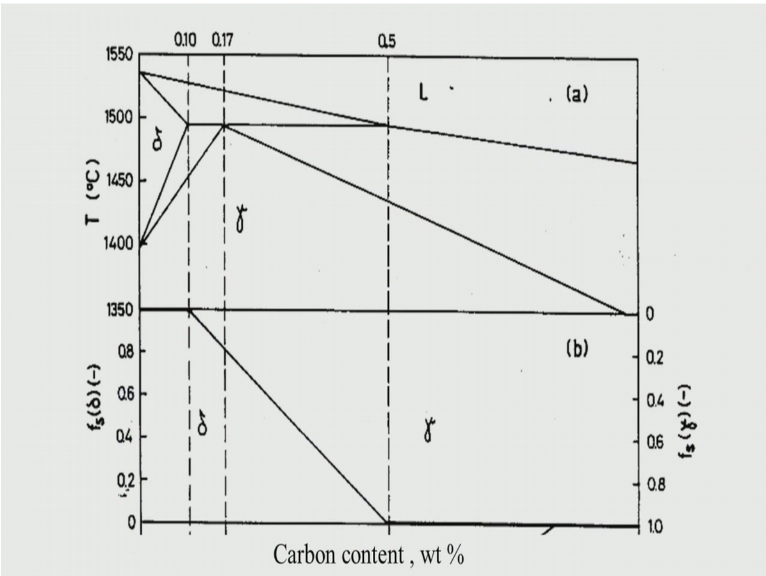

Now, let us come to the; you know well known iron carbon diagram. So, let us look at the high temperature portion of the iron carbon diagram this is iron carbon diagram at the high temperature portion; that means, from liquid during solidification what are the phases you can make out from this high temperature region this is the peritectic temperature it starts at 0.1 percent carbon ends at 0.5 percent carbon and peritectic composition is at 0.17 percent carbon.

So, just try to see how solidification take place say if you have a carbon steel the amount of carbon is 0.05. So, what is happening during solidification delta initially it is liquid then you have delta plus liquid and then solidification is complete is in delta mode only.

So, when the carbon is less than 0.1 percent carbon; that means, less than the peritectic range we are solidification through only delta then finally, this delta will in the solid state will go to gamma. So, during solidification we have only delta and only at lower temperature during cooling we have gamma and delta to gamma is taking place relatively high because the low carbon means you know liquidus solidus everything is relatively high.

So, solidification is taking place through delta and delta remains for quiet sometime depending on the carbon as we have very low carbon delta remains for quiet it comes down to quiet low temperature then only it transforms to gamma here this is delta plus gamma and this is finally, gamma and if the if the carbon concentration is more than 0.1 then what is happening initial solidification is through delta only. So, it is let me come down here.

That means above this temperature it is a 1500 temperature above the temperature of the peritectic temperature we have only delta and when you are reaching the peritectic temperature delta plus liquid is generating gamma through the peritectic reaction delta plus liquid is gamma this is a peritectic reaction.

So; that means, when we are in this region; that means, 0.1 to 0.1 seven initially liquid delta plus liquid then we have here gamma plus delta plus gamma and finally, gamma; that means, that the peritectic temperature is lower than the peritectic temperature solidification is complete at this point.

Now, when you are in this carbon range; that means, 0.17 to 0.5 what is happening initially again solidification is through delta only. So, initially delta plus liquid then at the peritectic temperatures some of the delta and liquid is only transforming to gamma and then below the peritectic temperature still we have liquid, but it is gamma plus liquid this is the gamma plus liquid zone to phase zone.

So, solidification is not yet complete we have initially liquid delta plus liquid then gamma plus liquid and then solidification is complete at relatively lower temperature. So, you see the solidification range temperature range is increasing as you are increasing the carbon. So, finally, it is complete at lower and lower temperature.

Now, look at what is happening at a carbon concentration more than 0.5 at this composition solidification is through liquid to gamma and then it is completely gamma. So, there is no stress of delta. So, the when it is less than 0.100 percent delta when the carbon concentration is more than 0.5 it is 100 percent gamma in between 0.1 to 0.5 it is a mixture of during solidification is a mixture of delta and gamma.

Finally everything is gamma, but during solidification for carbon concentration less than 0.1 it is 100 percent delta between 0.1 to 0.5 it is a mixture of delta and gamma as you are increasing the carbon. It is becoming more and more gamma during solidification, but when carbon concentration is more than 0.5 say 0.6, 0.71, it is 100 percent gamma solidification and look at what is the solidification range, it is quiet here, it is relatively less. So, this you can make out that the solidification temperatures are changing at solidus temperature. This is the equilibrium solidus temperature with segregation. This will be called still lower. So, the it will become much more wider solidification temperature range as you are going to high level of carbon with more solidification this become more wider.

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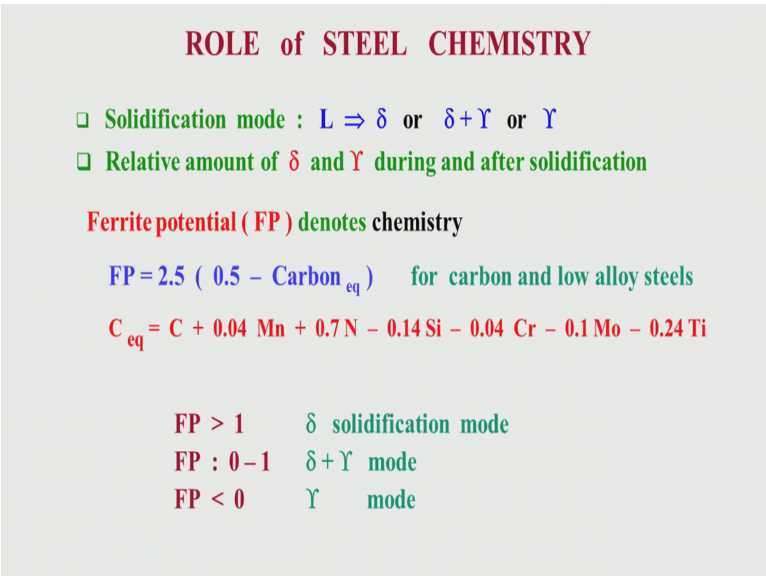

So, now if you look at the role of steel chemistry in iron you know plane carbon or low alloy steels. So, the solidification mode as I was telling you can be three types liquid to delta or liquid to delta plus gamma or liquid to gamma; that means, 100 percent delta 100 percent gamma in between 0.1 to 0.5 it is a mixed mode delta and gamma.

And solidification is completed at relatively lower and lower temperature as you are going to higher and higher carbon. So, now, some you know investigators they have devised one term called ferrite potential; that means, what is the amount of ferrite when the solidification is just complete. It depends on the chemistry in iron carbon diagram I have showed it is it depends only on just carbon, but in steel normal steels you do not have just carbon you have other alloying elements like manganese silicon things like that.

So, what is important is to understand the carbon equivalent how the carbon equivalent is calculated look at there is carbon plus; what is the goal of other alloying elements on carbon activity it is depends it depends on that. So, manganese then nitrogen silicon chromium moly titanium and look at some of the; you know manganese it is plus; that means, it increases the carbon activity. So, it is basically a like carbon forms you know austenite is austenitic stabilizer manganese also austenitic stabilizer nitrogen also austenite stabilizers. So, these are plus. So, 0.04; 0.7 these are the factors which will indicate what are the; you know relative effects of manganese and nitrogen on carbonic equivalent.

Look at other elements silicon chromium moly titanium these are ferrite stabilizers. So, this will decrease the carbon equivalent unlike manganese and nitrogen. So, minus 0.14 minus 0.04 chromium 0.1; so, people have found out these figures after lot of experimentations.

So, let us take this in equation of carbon equivalent there; there are other equations also, but this is most popular equation, which is normally used for identifying the carbon equivalent with respect to solidification. There may be other carbonic equivalent formula, but that is with respect to some other things, but let us talks about; what is the carbon equivalent with respect to solidification; that means, when continuous casting is taking place how the different alloying elements will affect the carbon equivalent. This is important because this carbon equivalent will determine instead of just carbon; carbon equivalent will determine how the solidification will takes place through delta gamma or delta plus gamma.

Where from this 0.5 is coming basically is from this particular this is 0.5. So, look at this figure here when solidification is taking place for any chemistry less than 0.1 any carbon less than 0.1 percent carbon with 100 percent delta.

When solidification is taking place for any carbon which is more than 0.5 it is 100 percent gamma in between from the liver we can find out what are the relative portions of delta and gamma as you are increasing carbon from 0.1 to 0.5 it is increasing from 0 to 100 percent.

So, this you know relative portion has been basically shown in this figure. So, you just put any. So, say carbon equivalent is a 0.1 then what is going to happen 0.5 minus 0.1 means 0.4 into 2.5 is basically 0; that means, as I was telling you look at this figure when you have 0.1 percent carbon. Its ferrite factor is basically one not 0 it is I just made a mistake it is one it is 100 percent ferrite.

So, basically 0.5 minus 0.1 is 0.4 into 2.5 this is one. So, when ferrite potential is one or more than one thickness it is a delta solid or more than one it is delta solidification say 0.05 percent carbon. So, 0.5 minus 0.05 basically means 0.45. So, 0.45 into 2.5 is more than 1. So, when ferrite potential is more than one this indicates it is delta solidification; that means, for any carbon or carbon equivalent less than 0.1 we have delta solidification mode.

So, let us take a carbon equivalent of 0.5. So, what does it indicate 0.5; 0.50. So, it is basically 0 if it is more than 0.5. So, it is a 0.6 0.5 minus 0.6 is minus 0.1. So, this is minus. So, when carbon equivalent is more than 0.5 ferrite potential is negative so; that means, it will indicate austenitic mode of solidification.

So, I think it is clear then ferrite potential is more than one; that means, for all carbon equivalent less than 0.1 we have delta mode of solidification when carbon equivalent is more than 0.5 ferrite potential is negative. We have gamma mode of austenitic mode of solidification and in between; that means, ferrite potential is between 0 to 1; that means, carbon equivalent is between 0.1 to 0.5 we have delta plus gamma mode of solidification.

So, ferrite potential is an indication of chemistry simply if I simply describe it, it is an indication of it denotes chemistry in terms of the carbon equivalent of a particular grade for plane carbon or low alloy steel. So, if we know what are the alloying elements present they can find out carbon equivalent and if you know the carbon equivalent from this figure or this relation we know; how the solidification is taking place whether through delta mode whether through gamma mode; what is the relative proportion of delta gamma at the end of solidification just at the end of solidification.

Beyond that it will again change please try to look at this figure this relative proportion is at that the end of this solidification here then as you are going to lower and lower temperature it is changing relative proportion will change. It will no longer remain what it was at this peritectic temperature.

So, after solidification also relatively you know here everything always gamma is forming here gamma is forming, but at this temperature is a combination of delta plus gamma. So, relatively delta gamma will change beyond solidification, but what we are talking is at this particular temperature; that means, at the peritectic temperature what is the situation at the end of solidification; what is the situation that is what is important.

So, I think you have understood what I mean by the role of steel chemistry how it affects the mode of solidification; solidification sequence whether to delta or gamma or a combined mode of delta plus gamma this is very important to understand.