Steel Quality Role of Secondary Refining and Continuous Casting
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Module – 08
Lecture – 46
Grade - Specific Casting Parameters : Part II

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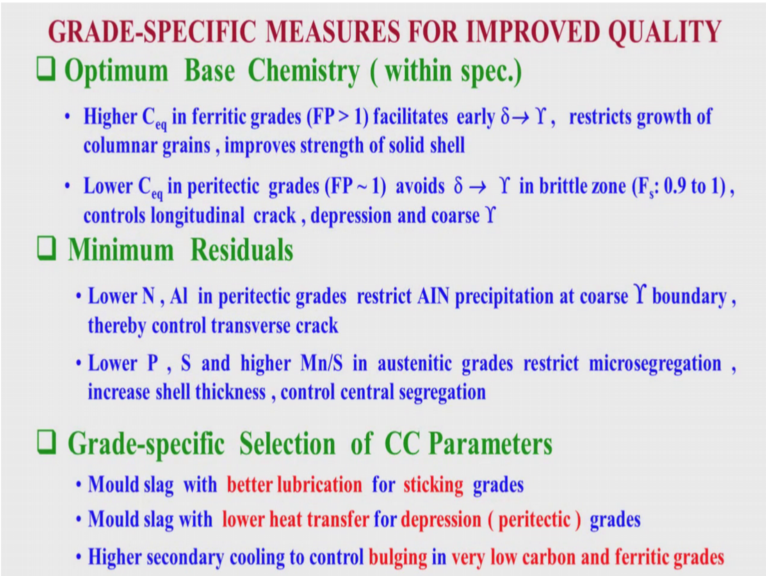

When we are talking of optimum base chemistry, then what we are telling is in higher carbon equivalent in ferritic grades; that means, grades like says 0 3 0.03 percent carbon or say silicon steel or say 430 stainless steel these are ferritic solidification. So, what happens in ferritic solidification. Solidification is totally through ferritic mould even after completion of solidification delta ferrite continuous and delta to gamma transformation in solid stake solid, state takes place at much lower temperature. So, what is the issue here? Issue here is fast, the solid shell which is delta ferrite is relatively soft. I have told you the high temperatures strength of delta ferrite is much less maybe about 20 percent or 15 percent of that of high temperature strength of austenite solid shell.

So, this for ferittic solidification the issue is soft ferrite which is creating the problem which might create problem there might be crack formation because it cannot with stand the. So, you have static pressure and takes like that. Another issue is because the delta to gamma is taking place at much lower temperature there is a possibility of delta grains of delta growing to a quite big size. So, delta if the delta grain size are big then also it is not a desirable situation the problem of crack formation is also there. So, there this restriction of this growth of columnar grains of delta, initial solidification is only columnar I have told you. So, you can control the growth of the columnar grains by how by adjusting you know carbon equivalent; that means, the chemistry; that means, you are increasing slightly the carbon equivalent you are increasing in stainless steel family slightly the nickel equivalent by chromium equivalent.

So, by that process you are trying to induce delta to gamma at higher temperature. It is normally at very low temperature much below solidification competition. So, you are alloying and the you know for this type of grades the solidification n temperature is quite high may be at 1400 may be 1450 so; that means, delta is remaining at high temperature during cooling for quite some time; that means, there is a scope for increase in delta grains delta columns you know, columnar grains have delta. So, this delta to gamma transformation in solid state can be brought down at brought up. That mean that incidence of delta to gamma transformation can take place at higher temperature if you slightly increase carbon equivalent.

How do you use carbon equivalent? You can use slightly carbon you can use slightly nitrogen you can use slightly manganese, all these are you know are in the carbon equivalent positive elements in the carbon equivalent, because they are strengthening the austenite rather than the ferrite. So, austenite you know formation will be enhanced by using slightly higher carbonic unit. Whatever I am telling is of course, within specification you cannot go to a carbon or nitrogen or manganese which is beyond specification; obviously, you should not do that. Within specification whatever possibility is there you can slightly adjust it; that means, for very much ferritic grades you slightly increase carbon equivalent that is the solution, but in a peritectic grades like you know when with carbon equivalent is around 0.1 or nickel equivalent by chromium equivalent is around 0.55 for ferritic for stainless steel family.

So, there what we have to do. Here the solution was slightly increasing carbon equivalent, but for the peritectic grades the solution is slightly lowering the carbon equivalent or lowering the nickel equivalent by chromium equivalent in stainless steel 304 grade. Which I have just discussed few minutes back. So, there by what you do you avoid this delta to gamma transformation in brittle temperature zone. Here delta to gamma is taking place in the solid area in delta area only and at quite high temperature, if it does not take place at high temperature then what happens delta grains will continue to grow. So, you have codes columnar grains that might create and if the if there you know super heat is also high; that means, the columnar grains will be quite codes there will be extending from the surface towards the centre of the cast product they are might be breakage of slab or bloom this way we have observed for ferritic stainless steels or say you know, silicon steels or very low carbon steels, because of soft ferrite and the ferrite columnar grains of ferrite extending almost was the you know central region.

So, here the solution is slight increase in carbon, equivalent for ferritic grades. For peritectic grades which is having a chemistry carbon equivalent around 0.1 or for stainless family the nickel equivalent by chromium around say 0.5 slightly higher than 0.55 may be 0.56 or 0.7. So, their what we do we lower the carbon equivalent So that delta to gamma transformation does not take present this brittle temperature zone. So, depending on the grade we have to make some adjustments. In chemistry minor adjustment in base chemistry within specification of course. Then I have talked about the effect of residuals. What I have talked about in peritectic grades, I have mentioned that you have very coarse austenite grains.

Why austenite grains are coarse? Because of depression formation the heat transfer in the mould is effected. Because of that the you know the cooling rate the casting rate also comes down, because of that the austenite grain grains become quite coarse and if you the austenite grains are coarse then what is going to happen. The grain boundary area will be less I think you appreciate this if the grains are finer the grain boundary areas are relatively more. If the grains are coarser the grain boundary areas are relatively less. So, if you have coarse austenite grains then what is going to happen? The grain boundary areas are relatively less and then this formation of aluminium nitride or narmium nitride or you know vanadium nitride I have talked about this.

When this happens? When this precipitation of aluminium nitride vanadium nitride or you know (Refer Time: 07:31) nitride when they do a form. They form around say 800, 700 degree centigrade. So, if you have a coarse austenite grains the boundary area is relatively less. So, the precipitation density at the boundary areas will be relatively more. If the boundary area is more same amount of precipitation will lead to relatively less density of precipitation. But if you have coarse austenite grains means the boundary areas are relatively less. So, the same amount of precipitation you have high density of precipitation. And this grain boundary areas become brittle. So, that is why this particular temperature range I have mentioned earlier around 700 around 7 650 around 750, this is again a low temperature brittle zone.

So, we have to avoid the zone we have to avoid formation of this nitrides. So, what is the way out? Your nitrogen has to be low aluminium has to be low. Normally we do killing with aluminium, but for that we need only maybe 0 2 aluminium, but sometime people use more of aluminium. So, unnecessarily you have more aluminium in steel which might create problem this type of problem in peritectic grades in grades which are having about 0.1 percent carbon. Or in grades like 304 austenitic stainless steel. So, we have to be careful about peritectic grades to we must have lower nitrogen aluminium and we have to be careful about micro alloying elements like (Refer Time: 09:07) and vanadium in this grades. Then I have talked about austenitic solidification grades where the solidification is taking place totally through austenitic mould.

So, what is happening there? There we must have lower phosphorus sulphur and higher magnesium by sulphur ratio. In austenitic grades I have given you example of you know. AISI 310s it is austenitic solidification. So, if you can reduce this phosphorus sulphur the incidence of defects inter columnar cracks in slab is much less. So, for such type of grades control of phosphorus sulphur and higher manganese sulphur assume, still higher importance. So, it is very important there. It is important in all grades, but it is very important in austenitic grades. We must control phosphorus sulphur and use higher manganese by sulphur in grades of austenitic solidification. What are these grades? In normal you know carbon steel or low alloy steels this grades are having carbon content of say around 0.25 0.3 0.4 0.5 mode the carbon mode is the austenitic solidification, mode problems of micro segregation. So, we have to must have low phosphorus low sulphur and higher, manganese by sulphur ratio because the shell thickness is an issue here if the shell thickness is less, because of high micro segregations. They cannot with stand the pressure from ferrostatic pressure. So, there will be crack formation the central segregation is also a problem the central segregation is a problem in general for all grades.

But it is quite prominent extent of the problem is quite high form you know austenitic solidification grades. So, I have mentioned about you to you about you know mechanical soft reduction which can take care of this to certain extent. So, that will come under continuous testing parameters use of mechanical software action, but as far as a deciduous is concerned in has to be low. So, what are the strategies them? First we understand from the chemistry how the solidification is taking place that is the first requirement. We if we know how the solidification is taking place then we can know whether it is a dendrite what it whether it is a if it is a ferritic or either ferritic or austenitic type of solidification; that means, the 2 extremes in the chemistry range then we know that these are sticking type of grades. These are bulging type of grades.

So, that is one type of solidification characteristics. And if the chemistries around 0.1 percent carbon equivalent or is around 0.55 nickel equilibrium might be cone by chromium equivalent for the stainless family, then we know there is those type of chemistries or grades we will indicate depression surface depression whether longitudinal or transverse. So, if you understand what is the solidification characteristics, then we can understand or know what is the type of you know solidification characteristics whether it will dip been depression prone, or there is a you know sticking prone or bulging prone. And understanding that then we can device the casting parameters accordingly, as I have mentioned. If it is a sticking grades stack of grades; that means, for very low carbon or very high carbon the mould slag should have better lubrication because here the lubrication is the issue, because it is a sticking prone grade.

So, what is sticking? The shell we will try to touch the mould therefore, the mould slag which is present in between the mould surface and the solid shell. It must resists that. So, the lubrication has to be better there. Accordingly you can you know you can use different oscillation characteristics I have told you know when this sticking is the issue then we have to be careful about better lubrication you know, the friction between the mould surface and the shell surface has to be control, otherwise will be sticking there will be you know lot of surface defects and the there might be you know break formation. But if you have depression grades, if you have casting depression grades which are peritectic grades, what do you they are heat transfer of the issue depression is the main problem.

What is why is this problem? Because this delta to gamma transformation is taking plane in the brittle zone, when the solid fraction is between 0.9 to 1. So, they are what do you do you have moulds you use mould slag which has characteristics of lower heat transfer.

So, the heat transfer is the issue there un likes sticking grades, but the lubrication is the issue. So, you see depending on their behavior, solidification behavior how they behave during continuous casting we have to use our casting strategy accordingly. Again I have tell told though this grades the sticking type of grades this sticking is taking place within the mould below the mould same grades we will undertake we will rather under show bulging tendency.

So that means, you have to control bulging in very low carbon and ferritic grades. These are the grades you know which indicate sticking tendency. The same grades will indicate bulging tendency below the mould. So, they are the secondary cooling has to be such that the temperature of the solid shell is broad down relatively faster. Than only you develop the strength of the shell because it is delta ferrite the strength is low. So, the low solid shell is prone to crack formation. So, therefore, you slightly higher secondary cooling and uniform secondary cooling gradient of secondary cooling is important do not you suddenly high and suddenly low. That might create temperature gradient it has to be uniformly coming down from top to bottom of secondary cooling, but relatively the intensity has to be slightly more for this type of grace where you have bulging.

Then you will can resist crack formation. So, the 3 strategies either selection of continuous casting parameters, based on there what is their characteristic. So, grade specific we call it grade specific selection of continuous casting parameter. Or you use optimum base chemistry I have again mentioned, depending on whether it is you know depression grades; that means, where the carbonic (Refer Time: 16:12) around 0.1. So, what you do? You slightly increase a slightly rather decrease the carbon equivalent. So, that you can avoid delta to gamma in the brittle temperature region. So, they are by you can control stress generation additional stress generation from delta to gamma. Transformation in towards the end of the brittle temperature region, this is the brittle temperature.

So, if you can avoid delta to gamma in this region, your depression tendency will be less that is what you do by using lower carbon equivalent or as I have shown you given the example by decreasing then nickel equivalent by chromium equivalent to a value which is lower than the 0.55 which is the start of the peritectic chemistry. If it is lower at lower value of the peritetcic chemistry. So, the delta to gamma transformation takes place at lower than the solidification completion temperature; that means, when the brittle temperature we can avoid. So, this is the strategy which we were up. So, either you use the base chemistry within specification adjust it accordingly to take care of the particular solidification characteristics. For ferritic grades use higher carbon equivalent I have mentioned why and for peritectic grades you use lower carbon equivalent. Of course, within specification I am again and again telling within specification whatever range of chemistry you have within that you can make some adjustment minor adjustment So that you can avoid this brittle temperature zone for peritectic grades.

And you can have delta to gamma transformation relatively at high temperature and restrict growth of delta ferrite columns delta ferrite columnar grains. So, this is a strategy which you which you adopt minimum residuals of course, is required in for all grades, but for certain grades it is more pertinent. Which are the grades either in peritectic grades you should have low nitrogen or aluminium, to avoid formation of aluminium nitride or you know micro nitrides or micro alloyed micro alloying elements like niobium, nitride, or (Refer Time: 18:38) nitride. At the course austenite grain boundaries I have told you, which happens in you know peritectic grades which is a problem in peritectic grades because of you know, surface roughness. Because of the surface roughness heat transfer is slightly lower. And because of that you have you know course austenite grains and because of that grain boundary areas are relatively less and the density of this precipitations harmonium light trade will precipitated in all grades.

But if the grains are coarse austenite grains are coarse, then the density of aluminium nitrate precipitation at the grain boundaries relatively more for coarse grains. Because grain boundaries are less. So, that is why this is a problem for peritectic grades where the grains are relatively coarse. So, we have to be careful about this. And then as I have told you phosphorus sulphur and manganese by sulphur has to be low in all grades to control micro segregation, but this is particularly important for grades or austenitic solidification is their. So, they are you have to be more careful. So, these are the 3 broad strategies one should follow. Either selection of casting parameters understanding after understanding the solidification characteristics. So, we call it grades specific selection of casting parameters. We know how a particular grade we will behave tuned solidification.

Accordingly we decide the casting parameters. Then we know the broad you know how the broad grades the grades will broadly follow a solidification pattern, accordingly we adjust the you know in small amount we adjust the chemistry within the specification to take care of the problems. I have given several examples of this. Then of course, residuals you have to control whether it is phosphorus sulphur and manganese by sulphur ratio for controlling segregation. Or for you know avoiding the brittleness at around say 700 degree centigrade in particularly for the peritectic grades. When the austenite grains are coarse. So, we must have relatively lower nitrogen aluminium in this grades. Un necessarily high aluminium we should avoid, and try to use lower nitrogen it try to control nitrogen I have mentioned earlier. Then nitrogen is a residual we do not want high amount of nitrogen un necessarily in any grade. So, again control is very important. So, these are the strategies one should adopt to enhance the quality of steel cast product and if the quality of the cast product is good than for the role product; that means, after rolling you have a good quality on the surface. I think I have covered most of the issues related to the quality of cost product.

Thank you very much.