Steel Quality Role of Secondary Refining and Continuous Casting
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Module - 08
Lecture - 49
Identification of Genesis of Quality Problems Through Metallographic Investigation : Part III

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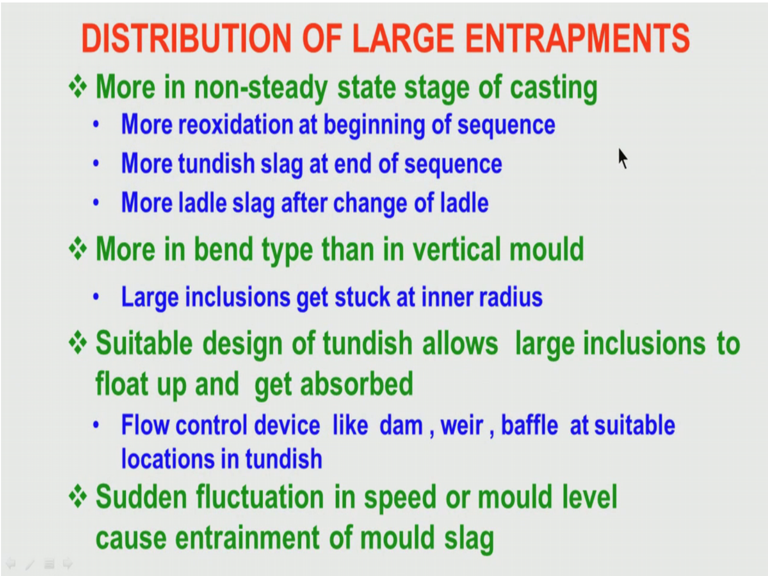

In a cast product: and cast product is finally you are rolling to have a roll product, so the distribution of the large entrapments then on uniform. As I have told you, you have to worry about the large entrapments only not find inclusions small inclusions, but this entrapments, then only uniformly present in the cast product. And since they have not uniformly present in the cast product and say as since they have not uniformly present in cast product they will also not be uniformly present in the roll product. So, let us see what they are present. I have mentioned this earlier, but again I am (Refer Time: 00:49) because this is very important; because in the non-steady stage of casting normally you find this entrapments.

What is the non-steady state? That means, at the beginning of a sequence, when you are just beginning a sequence. Then you will find reoxidation- possibility of reoxidation is there because of shrouding is not yet complete. So, some amount of exposure will be there in the liquid steel at the beginning of the casting so more of reoxidation at that stage. So, at that particular stage we will have more large entrapment due to reoxidation. Then at the end of the sequence there is a possibility in a getting tundish slag entrained, unless you take care of it at the end of sequence that you do not allow the tundish slag to come in the mould. You allow some amount of small amount or liquid steel to remain at the end of the casting. So, that at the bottom of the tundih you have some steel also. If you allow that to come in then along with their some small amount of slag also will come.

So, the end of the sequence there is a possibility of tundih slag entrainment. And then at the stage of ladle change sequence means there will be several heats. So, one ladle means one heat, so when one ladle is getting emptied the ladle is replace another ladle we will come and the ladle is allowed to you know a team. That means, there are liquid steel from the ladle we will fall in the tundish.

So, the slag should not be a rather allowed to come in the tundish from the slag, from the ladle when it is getting emptied towards the end of the heat the ladle is getting emptied. So, liquid steel is coming out. On top of it is slag, slag should not be allowed to come from the ladle to the tundish. So, you allow either there should be a you know slag detection system, it will not allow the slag to come or you allow some amount of liquid steel to remain in the ladle. So, that slag does not get inside.

So, you have to be careful about those. That means change of heat there is a possibility of some steel what is that slag entrainment, so possibility of entrapment. Then in bend type of vertical mould. In bend type there is a possibility of inclusions then in vertical mould. I have mentioned it earlier, when you are a vertical mould the inclusions in mould when they are floating up there is a possibility of the they will go to the top and get absorbed by the slag, but you have a bend type of mould then there is a possibility that some amount of inclusions we will get stuck at the inner radius portion. And the inner radius area will be relatively less clean. So, some amount of exogene has a entrapment will be there. So, this we have to be careful.

So, what I am telling is- it is not distribution is not uniform, not uniform along the length of the casting, not uniform along the width of the casting also. If you have a vertical mould then the width is more or less similar in you know clean less, but if we have a bend type of mould than the inner radius areas relatively near the inner radius areas relatively un clean; more defects will be there. Then the suitable design of tundish has to be done so that these large inclusions they float up and get absorbed by the slag. So, the design of slag is important so that they can absorb the inclusions. The design of tundish is very important, so the residence time of liquid steel in tundish is relatively high it does not immediately go into the mould. So, during the high residence time they can float up and get absorbed by the slag; this is very important.

So, flow control devices like dam, weir, baffle, at suitable location of tundish is important. Refractory property of the tundish ladle is very important, so that they do not disintegrate and get entrapped in liquid steel. Then sudden fluctuation of speed or mould level they can cause entrainment in mould slag. So, we know that at what stages there are possibility of large entrapments; that means at what stages of casting there is a possibility of poor cleanliness. And we know these are the locations where we have more defects, because possibilities of entrapment of large entrapment large inclusions are there in those locations. So, from during the casting itself we know certain areas we will have more entrapment. So, what we do? We keep those cast product separately, because we know intentionally if you want to roll it those role products we will have entrapments.

So, distributions of large entrapments are non uniform. So, when you are getting a defect product in a role product we know trying to co relate with the origin. If we know that you know certain stage of casting there was a fluctuation whether in speed or more level we can co relate. Yes, this particular area; that means, after may be one over casting there was a fluctuation for few seconds to be know in one about which are of the cast casting was cast. So, we know now that area of the casting after rolling it has gone to that particular location, so we can co relate with that. So this role correlation is very important.

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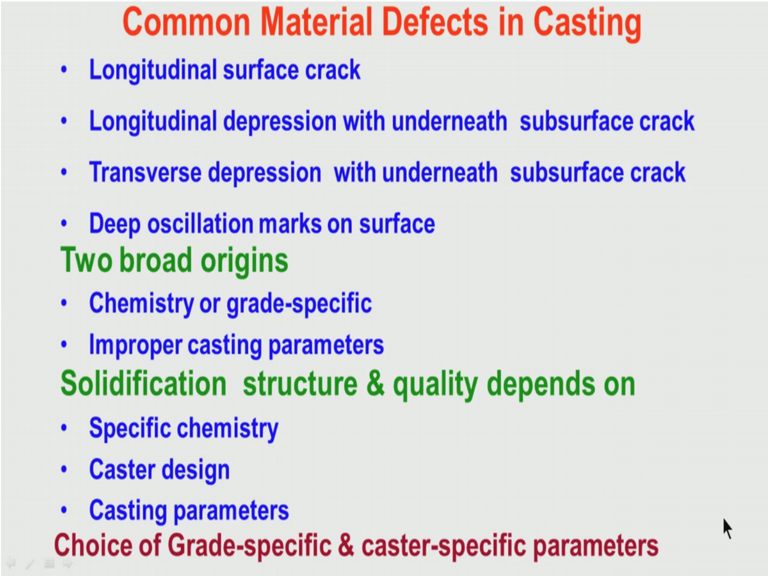

Then what are the common material defects in casting. This is again very important because when you are trying to correlate with different parameters I have mentioned the longitudinal surface crack there maybe. There may be longitudinal depression with underneath surface crack. Sometimes you are finding only crack, sometimes you are finding depression and below the depression underneath the depression there will be sub surface cracks. Then maybe there may be transverse depression with surface crack, there may deep oscillation marks on the surface as I have told you. And below the deep oscillation marks there may be powder entrapment then may be crack.

So, if you have the surface defects on the casting, and if you are rolling it to the final product then it will be easier to correlate. If you do not have the surface defects, but if you subsurface defects then sometimes it is difficult to correlate, there were from it is coming.

Then I have told you this material defects they can basically; material defects in casting I am not talking of entrapment I am talking of material like cracks and you know depression they can basically origin from two broad categories one the chemistry of particular grade. That means, sum grades are depression prone, so you will have more depression, more cracks on the surface, more deep oscillation marks for those grades. So, chemistry of that grade that is a origin. Or improper casting parameters, everything was at the casting parameters was not properly selected there was a sudden increase in may be speed, certain fluctuation that might create some defect; so this again important.

So, what is important the solidification structure and quality they are correlated. As I have mentioned specific chemistry is important casted design is important. What is meant by caster design? I have told you the mould: it can be vertical type, it can be a bow type; that means, there is a curvature in the mould. See if it is a vertical type then from entrapment point of view it is relatively better, but it is a bow type; that means, there is a possibility of the regions which are near the inner radius surface you know solid surface near the inner radius their might be some entrapment. Because, whatever inclusions are floating they might get entrapped in those areas, but in a vertical mould they will go straight away a vertically and get absorbed at the mould slag surface.

So, caster design is important. Again this bow type or vertical type because if there is a vertical type then first have to give a bending during bending of the strand after it comes out of the mould and then you have to un bended you have to straighten it; that mean you are putting some additional strain on the surface of the cast product. It might be of the strain the magnitude can be depend it will depend on what is the extent of bending, what is the extent of un bending, and at what rate you are giving this bending whether it is slow bending whether it is a fast bending. So, all these parameters kite might create lot of strain mechanical strain.

So, that caster design by castor design I mean that also. Then of course, casting parameters is very important. What is the taper you have used? You know I have mentioned the taper has to be slightly more for depression grades, because depression grades means mould shrinkage mould taper has to be mould; that means, the distance between the two plaits of the mould at the bottom of the mould is slightly less compared to the top of the mould.

Top of the mould is solidification has now started, bottom of the mould means solidification has gone to certain extent- say about 15 millimeter of shell thickness has already formed. That means, if the 15 millimeter solidification has taken place. That means, they little bit some shrinkage. So, you have to give some taper. That means, at the bottom of the mould the distance between the two mo two plates board surface of the plates is slightly less than what is that given the top that is called taper.

So, casting parameter mean taper; casting parameter mould taper casting parameter means mould taper casting parameter means what type of power using, what is the solidification temperature of the powder of the slag, what is the other characteristics of the slag, what is the viscosity; it all depends on what is the chemistry of the slag.

So, that is also important. Then what is important is how much secondary cooling you will give, it depends on the type of grade which is being cast. What is the intensity of secondary cooling, whether you will go for water cooling or mist cooling, whether you go for; what is the gradation of solidification, what is the gradation of secondary cooling- it depends on what is the extent of solidification. So, these are all important parameter these are casting parameters I am talking about.

Then you know I have talked about to take care of central segregation and central crack formation you can use mechanical soft reduction. That means, you are slightly decreasing the thickness of the cast product in his zone which is near the solidification front. I have mentioned the location of this is very important, intensity of this reduction is also very important. If you use less reduction it will be of no consequence no effect, if you to use too much of this that means too much of soft reduction you are doing mechanical reduction is too high then there may be crack formation.

So, intensity and location of mechanical soft reduction is very important. So, that is the idea you must have the idea where solidification is ending, where the solidification completion is taking place. You can use it through modeling, you can use it from the calculate what is the end result of the solidification end stage of solidification. So, you have to have mechanical soft reduction in that area and the intensity of reduction also is very important.

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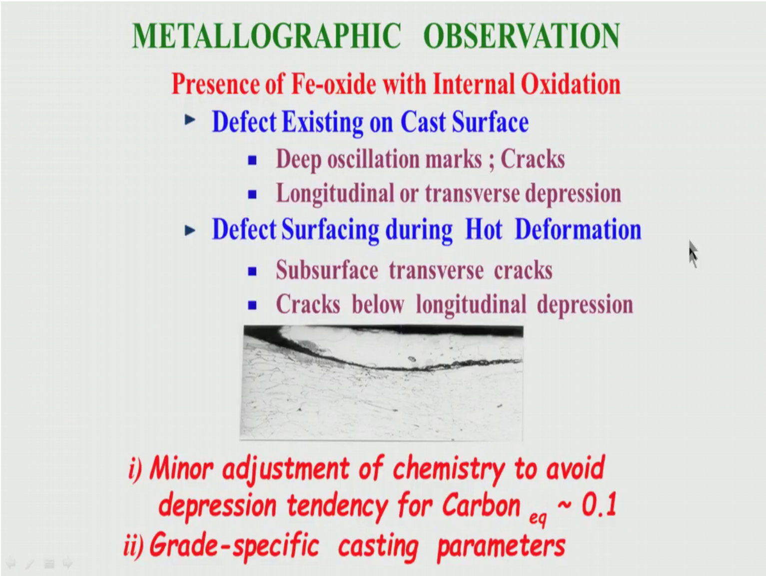

So, now let me give some examples like certain defects how does it look like metallographic observation; like you know this one defect we are found that the after you have from the slab it has been rolled to each of product. We find that the crack is extending from the surface and going inside the below the surface. So, we wanted to observe it. First we observe this area, this is the area below the crack and the we observed the area above the crack and below the surface. What we see is this particular area there is internal oxidation; there is a grin growth in this particular area. What does it mean as I have mentioned earlier. This pre presence of iron oxide with internal oxidation and there is a grain growth; that means this crack whatever you are saying now this must have been you see it is coming it is joining to the surface originally it might have been subsurface, but during rolling it got exposed to the surface, because of that there is an internal oxidation; there is a grain coarsening.

So, this is important. How it can happen? That means, defect was existing near the cast surface; I have put it here on or slightly below the cast surface. It may be due to deep oscillation marks because under that there may be cracks or there maybe cracks also there maybe deep depression and under the depression then maybe crack. If there has a depression normally below the depression the gain structure is coarse I have mentioned you earlier because the solidification rate the heat transfer rate becomes slow, slightly under the depression. So, that particular area the means the grains are coarse that area is relatively week. So, there might be crack formation also during rolling.

So, all these possibilities are there. That means, defect existing in the casts surface or cast product itself either on the surface or slightly below the surface; that has created this cracks. And defect has surface during hot deformation. That means, subsurface transverse cracks were there or cracks were below longitudinal depression either on the surface or below the surface. So, they have come to the surface during hot deformation.

So, normally these type of defects as I was telling you- you will find near the edges and in grades which are so called we call peritectic grades. That means, the carbon equivalent is around 0.1 or in stainless steel family it is a 304, grade where the chemistry is near the peritectic start region around 0.55 nickel equivalent by chromium equivalent. So, what we can do? If you find such type of defects, that means we know what the defect has form so you can minor adjustment of chemistry to avoid this depression tendency for this type of carbon equivalent 0.1.

We may slightly make it lower. If you make it lower; that means, delta to gamma transformation we will take place after solidification. So, this delta to the strain formation due to delta gamma transformation depression formation due to delta gamma transformation will not occur and the overall depression will be less. Or we can: first is this chemistry adjustment, another of course is grade specific casting parameters. We know this is the depression grade, so we know that heat transfer is an issue so accordingly we have to select our casting parameters.

The characteristics of the casting parameter should be such that the heat transfer is suitable. Uniformity of addition of casting powder is important so that when a localized zone at the periphery of the mould surface there should not be a gap formation and there should not be a depression formation. So, it should be uniform, so that heat transfer is uniform that is one requirement for these grades.

So, heat transfer control through proper selection of casting powder is very important. Normally, since this is a depression grades you have slightly more taper compared to sticking grades. Taper maybe we have to give 0.9 percent or 1 percent for such grades. For sticking grades it is less maybe 0.7 percent, 0.6 percent, 0.65 percent. So, that is why I mean by grade specific casting parameters based on what is the solidification characteristic you decide what should be the casting parameter, what would be the casting powder, what should be taper, what should be secondary cooling, intensity of secondary cooling, all these issues you can decide what should be the mould frequency, oscillation frequency, what should be the you know amplitude of oscillation. You know this type of grades depression grades also I have very deep oscillation marks which is the defects.

Oscillation marks we will always be there in all grades, but certain grade you have deep oscillation mark so what do you do. You try to reduce the negative strip time I have mentioned earlier. How do you do that? You increase slightly the speed that is one way, you increase the frequency of oscillation, you decrease the amplitude of oscillation. That means, if you have this ideas, if you have this knowledge, and you know that casting a depression grades did you accordingly decide your casting parameters, so that you have less depression.

Again, for such grades the problem will be course austenite grades I have mentioned. So, how do you do that? Again heat transfer control it should be prepared for that depression is less. If the depression will be the surface will be good, if the surface of the casting is glued there will be less depressions hot spot formation is less. So, the grains austenite grains also will be relatively finer. Now this is; the earlier one was there was no if there was a crack there was no entrapment, so basically the crack in cast product was the problem.

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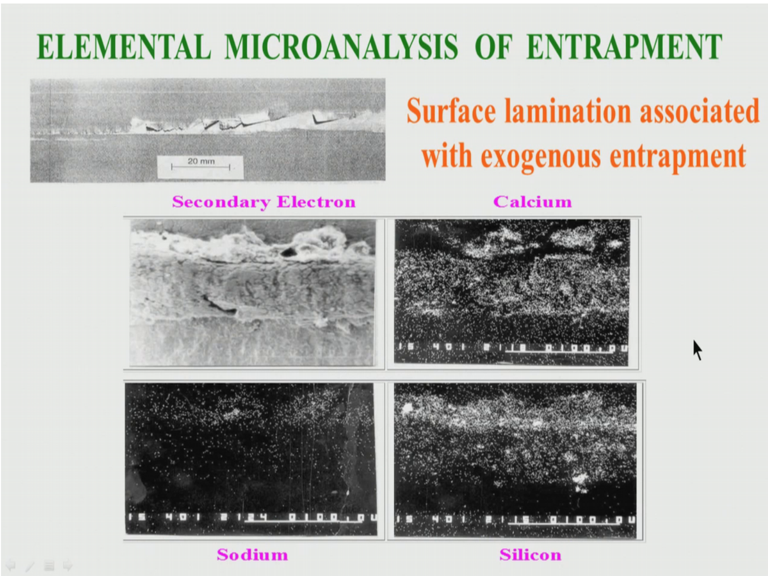

In this, now I will talk about and entrapment. So, entrapment is creating this surface lamination. You see this surface is the actual surface of the product; rolled product. You see it is sort of tearing there is some additional surfaces getting generated. It is very codes you can see it with normalize itself. So, what do you do? You take a small piece from here, this is actual sample surface this is a surface lamination. So, then if you just take the surface you remove that top surface you will find we need the surface there are some entrapments, some dark materials it is nothing to do with the surface you know the nothing to do with the normal product of the matrix; it is you can make out there is something different.

So, you take that material, cut a small piece, put it under secondary SEM, then in under SEM with secondary electron mould there is nor normally image mode you will see this defect has been magnified. So, these defect we look like this. And when you see what this present there you will find some calcium is present, some silicon is present, some sodium is present; that means, it is basically combination of calcium oxide, silicon oxide, sodium oxide, there will be some aluminium oxide also. But since sodium is present; that means, sodium oxide is present we can infer that it is basically mould powder has been entrained.

So, exogenous entrapment of mould powder; why mould power because sodium is present has there been just calcium; here you see calcium is present silicon is present sodium is also present. If you take fluorine analysis you will find as fluorine is also present, aluminium also will be present. So, you can make out from the exogenous has entrapment what is the source. So, mould powder entrapment has cause this formation of this lamination. So, you can know depending on whether it is entrapped, what is the type of entrapment, what is the source of entrapment; if it is a crack why the crack has formed. Like the earlier example I gave this crack formation is associated with internal oxidation grain coarsening and so you know that crack must have been present earlier, and it has been linked to the surface during early stage of controlling itself.

That means, it was pre existing in the cast product. So, there must have been some crack or depression in the cast product. So, this analysis from this way you can know metallographic analysis and if you have the knowledge of the continuous casting, knowledge of steel making, steel refining; you know whether it is entrapment or you know whether it is crack, you know which type of grade you are casting, you know what is the type of solidification so you can tell what are the possibility fakes, at what stage there what is generated and accordingly in future in the defect has taken place; ok in future you can take some remedial measures.

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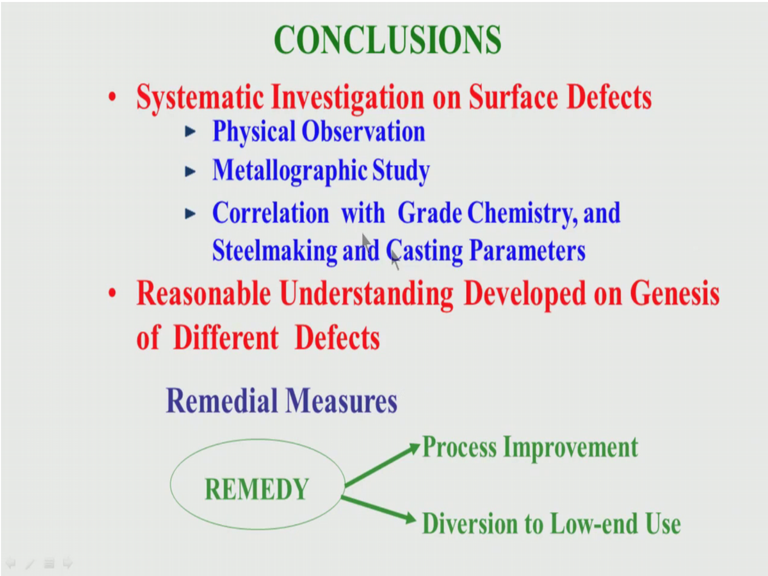

Now, let me conclude by observing that systematic investigation on surface defects in rolled products what we have done: we are physical made some physical observations, we have used lot of inspection good inspection facility, to find out what stage defect is there what is the frequency of the defect, what is the size of the defect shape of the defect. And then we have done some metallographic study. That means, we have taken samples from here, from defect areas carefully observing, what are the defect how does it look like and the normal with normal eye under microscope.

So, with metallographic study were found out what was the defects whether it was crack whether it is there entrapment, then we are correlated with the grade with the steel making and casting parameters. So, using all these people can develop some reasonable understanding on the genesis of different defects. This is very important. Development of genesis of different defects so you require physical observation; that means, good inspection, you require some metallographic observation study, you require good correlation with the chemistry and the steel making casting parameters; that means everything is required.

Here some knowledge is involved, here some practical ideas are in involved. So, this combination of theory and practice we will finally give you a lot of concrete information. So, what is the remedy suppose you are found that yes defective has is taking place. Then there can be two remedies: one is either you can do process improvement- process improvement involves some cost. So, you must know whether through this improvement; that means, you are using some you know investment what will be the extent of improvement. Or if you find that ok it is invest and it is too much then what you do is you live with the defect for those defects you divert follow and uses.

I have mentioned to you at the very first stage of this course that there will be certain defects, but it depends on what type of applications we will tolerate what type of defects. Quality of steel is application specific. The certain quality of steel can be used for different applications. A very stringent application we will equal very stringent quality. A very low in low end application you may have inferior quality

So, you can divert those particular materials for low end applications, where quality requirement is not that stringent. So, what is important is that you should know what are the application requirements, for what applications we required what quality parameters and you should also know how to achieve these quality parameters. Why quality parameters I mean residuals, entrapments, this control of residuals, control of entrapments, and control of defects in cast product. So, using this knowledge you can get the desirable quality which is required for a particular application.

Thank you very much.