Steel Quality Role of Secondary Refining and Continuous Casting

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Identification of Genesis of Quality Problems Through Metallographic Investigation: Part II

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Let me discuss these issues one by one this will be very useful, that in a product what are the quality issues what can what you can see actually has a problem or a defected product. Normally they can be manifested as I have told you either has a surface itself; that means, visible imperfection it can be a surface lamination, lamination means I have mentioned it is like two different surface, on the surface some additional surface has been generated that is called lamination. Sometimes some people call it a shell type of defect. So, it can be a surface lamination or shell, it can be a very thin line on the surface of the product particularly in a cold role product say it is a it is called a sliver; that means, is a very thin line of defect.

Normally it has been found to be associated with some slag entrainment a different stage of the sample preparation or may be the either they have been casting. So, some slag got entrained or even in tundish there is a possibility of entrainment or even is you know little there might be entrainment. So, finally, that slag is if it is has a good formability.

So, it will be manifested as a thin line which is called a sliver, either it can be surface lamination which is called shell or it can be a thin line which is called a sliver or there can be cracks or holes on the surface; that means, you find in the cast product there are certain cracks or may be small holes. So, these are really very crude defects.

So, we have to know why this has formed at what stage it as formed and then these are on the surface I am talking about, and there can be certain problems at the subsurface or internal defects which normally you do not see on the surface through a non destructive test you can see, or if you have a correct cross section then you can see sometimes you have to see the cross section, as I have told you in cast product the internal defects you can see only in a section in a cross section surface may be all right. But if you cut a section take a section view at different stages, then you will find some defects may be there are at the subsurface some defects may be at a inter in interior, some defects may be at the central location central line. So, all these central line you do not see on the surface.

So, you only you have to see at the section cross section. So, subsurface on internal defects also or sometimes manifested what you accordingly you have to see at those sections and then only you can see them their manifestation. Now genesis as I have told you it can come from the input cast material. So, if it comes from input cast material then what are the possibilities? I have told you the two broad categories either they are exogenous entrapment from steel making or casting; that means, still making means either they may secondary refining or during in the tundish from the ladle or during casting itself from the mould there maybe entrapment, moulds like may be entrapped there are other possibilities of entrapment also.

So, this is one or from the subsurface imperfection in casting, there may be a problem. These are normally surface of subsurface imperfection in casting, these are basically entrapment during steel making or casting; that means, exogenous entrapment, but another source is the casting quality itself; that means, there may be some imperfection on the surface of subsurface of the casting which are finally, generating in the final product. So, normally it can be grade specific; that means, certain grades we will generate certain quality issues or from the process itself from the casting process itself there if there are certain irregularities, then you might get some defects. So, these are the possible issues.

Now, what is important is identification of the root cause; that means, the genesis is essential for implementation of remedial measures. Maybe you are getting certain defects you want why do you want to know the genesis, because if you know the genesis then you can take care of it in subsequent stages, say defect has form at particular instance you do not want the defect to continue in subsequent stages also. So, if you know what was the root cause of the defect, what was the genesis of the defect specific reasons you have to identify; then in subsequent you know processing stages subsequent steel making secondary fining or casting stages or even (Refer Time: 05:10) stages you can take care of it. So, that is why it is important for identifying remedial measures what are the improvement measures, how do improve it this is very important.

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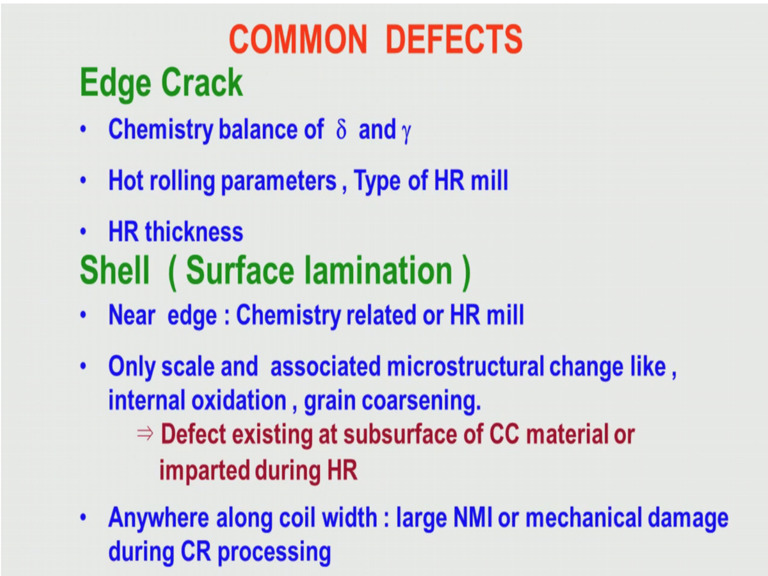

Now, I just talked about a few typical defects, which can form in the you know final role product, which are starting from the casting product, but after doing only some of the defects you can identify. Sometimes particularly this happens from a stain in stainless steel certain stainless steel you find that the edge of the you know role product or product there is some crack formation at the edge, we call it h crack. So, normally it has been found that there is a chemistry balance problem between delta and gamma; that means, in certain grade of chemistry if say 304 is a common stainless steel grade, I have talked about this the nickel equivalent by chromium equivalent up this grade is around say 0.55 only the peritectic. So, called peritectic (Refer Time: 06:24) we call it.

But if the nickel equivalent by chromium equivalent is very low in this grade; that means, it is going slightly towards the ferritic range, then what happens? Your continuous casting quality will be relatively better as I have told you increase the nickel equivalent by chromium equivalent or rather you yeah you decrease then nickel equivalent by chromium equivalent to make a slightly ferritic. So, that the delta ferrite to austenite solidification takes place below the peritectic temperature we below the end of solidification temperature, but in that process if you do not have much control then what will happen if the delta ferrite becomes more strong, then you might have be h crack; that means, normally in 304 your ferrite at room temperature at you know at slightly higher temperature should be around 4 to 5 percent.

But if it exceeds 6 percent if it becomes a 8 percent or 10 percent, then you have this problem of h crack. So, basically chemistry can play a role here, chemistry balance is very important or what is the important here is nothing to do with the chemistry or continuous casting if the hot rolling parameters; like what are the type of hot rolling mill you are using it is a stake and miller normal you know hot strip mill those are important. What are the temperature finish temperature that is important, if you role at low temperature the problem of which we are might be there. I f you role to very thin thickness there might be this problem. So, if you have a high amount of relatively high amount of delta in this particular grade there is a problem.

So, chemistry is important from the product quality point of view and form the processing point of view, type of mill and the thickness and the rolling temperature these are important. Then if you come to that defect we call it shall or surface lamination, this is a very typical and very recording problem in hot rolled materials hot rolled coil or even cold rolled coil. So, you will find this laminations surface lamination, now as I have mentioned to you (Refer Time: 08:32) or surface inspection is very important to identify at where this laminations are taking place. At this laminations taking place near the edge, if it is near the edge normally it has been found that it may be related to the chemistry or it may be related to that hot rolling problems also. It is related to chemistry means as I have mentioned for you know 304 grade I have given an example that there was a lamination and just below the lamination at the subsurface there was a crack.

So, this laminations near the crack near the edges are coming from you know defects cracks or depressions longitudinal depressions near the edges for grades, which I have the so called peitetric grades, that it around 0.1 percent carbon or 304 stainless steel. So, it is chemistry related; that means, here. So, we can control it has I have told you earlier by adjusting minor adjustment of chemistry. So, it is coming from mill you have to tackle it in a different way which I am not discussing in this particular session.

So, now in shell you might find that only you are having some scale and there is a change of microstructure like you know internal oxidation or grain coarsening, then you know the defect was existing at the subsurface of the con cast material. As I was telling you always or maybe sometimes when you have a depression defect, just understand in sub surface then might be crack the during hot rolling that crack is coming to the surface of the product. So, then what happens? Then you get internal oxidation because that crack which is a getting exposed during hot rolling. So, we will get oxidized. So, you call it internal oxidation, out of the crack from the surface it is going inside so; that means, there is a in grades of oxygen during rolling or during reciting. So, we call it internal oxidation.

So, you will find scale, we will find some micro structural changes like grain coarsening like internal oxidation. So, you know the defect was existing in the cast product itself at the subsurface level then only this signatures you will get you know internal oxidation scale, grain coarsening in the final roll product. So, we know if defects are present; that means, it has originated from the continuous cast material or it might be imported during the early stage of what rolling also. So, again you are to there is the important at what string whether it was from continuous cast material or imparted during hot rolling that is important. But since we are concerned about the product quality here the quality which is coming from the cast stage itself we have to be more careful about, that such defects do not exist in the cast material.

If there was a crack formation during hot rolling I mean due to say low temperature rolling their might be crack formation, that is a different aspect we have to take it you know take care of it during hot rolling. But if there was a crack subsurface crack existing in the cast material, which got exposed during hot rolling then the calculate is not hot rolling. It is forming during hot rolling, but the culprit is crack existing in the pre existing in the cast material itself. So, we have to identify at what stage this defect was generated that is very important. Now there might be this shell in the location of the surface lamination anywhere on the called weight or not any particular location.

So, normally it can be due to large NMI or it can be due to mechanical damage during cold rolling processing or not. So, if it is due to large NMI that means, the steel makers are responsible for it and the rolling, rolling mill people are not cannot be held responsible because it is because of large nonmetal inclusions which I have got entrapped in the steel either during steel making or casting stage. So, this might generate randomly you know at any location of the final roll product. So, if it is near edge then we know it may be due to lamination or it also may be due to hot rolling, you know they use edger. So, because of edger problem also it might take place. So, from the signatures in the final product in the rather a defect analysis you can know at what stage it has originated. So, that is very important. If it is originated during still making or casting then you have to do something you have to take care of it in a certain way if it was originated during processing then subsequence stages you have to take care off.

So, again I am repeating that proper defect analysis is very important to know at what stage the defect has been created, and from there with pran knowledge you have to correlate why it has been created. So, there subsequently you can take care of it.

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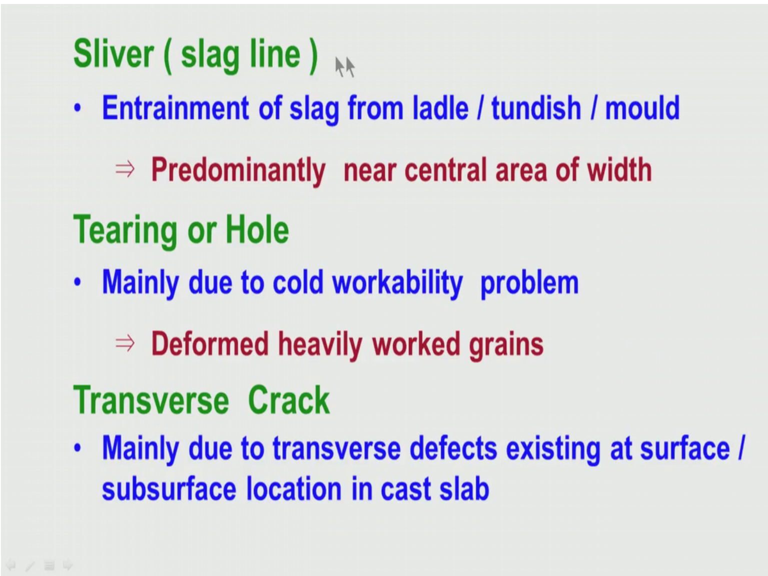

Now sliver as I was telling means another type of defect, it is basically some people call it a slag line because it is basically entrainment of slag it can be either from ladle or tundish or mould. It is normally it happens not was edge of the you know roll product, normally in the middle portion of the width of the product. Normally it has been found to happen and whether it is from ladle or tundish or mould as I have told you earlier you can identify this when you analyze through EDX or WDX; whenever this slag line is there you got a small sample put it on the scanning electron microscope, focus the electrons on that defect and see what are the elements present there.

If it is from the ladle it will have predominately calcium; that means, it is basically calcium oxide, reach in calcium oxide other oxides also be there, but relatively less if it is from tundish predominately silicon oxide will be there. So, silicon you know concentration will be relatively more silicon oxide. If it is from mould you will find some calcium fluoride or you might find some sodium oxide. So, those we will indicate the slag it is coming from the mould or it is tundish or from ladle. So, this slag entrainment gives a defect which is normally called sliver or a slag line of defect because it is basically coming from entrainment of slag during either during secondary finding or continuous casting.

Now, sometimes as I was telling use there might be a tearing or a hole generation generation of hole in the product, but normally it has been formed that it has nothing to do with the cast product, it is mainly due to cold workability problem; that means, whenever deforming heavily worked grains; that means, too much of cold deformation might generate tearing or hole. So, the continuous casting people or the steel making people are not responsible for it. So, I will not discussing in details this problem is really something to do with the cold rolling.

Now, we might find transverse crack. Now I have mentioned earlier this transverse crack is mainly generated you to transverse defect existing at surface of surface location of cast product, whether it is slab or bloom or billet. This transverse crack as I was telling you it can generate from transverse depression or deep oscillation marks; deep oscillation marks are basically having a transverse you know orientation. So, under those deep oscillation marks there might be cracks in the sub surface region. So, when you are finally, rolling that product those cracks which are just below the transverse depression they will come to the surface. So, we will find transverse cracks or defects generating in the product after rolling, but they were existing at the subsurface locations either at the root of the deep oscillation marks, along with transverse cracks you might find some powder entrapment also.

So, cracks along with entrapment, sometimes you find crack you do not find any entrapment whether it is from slag or alumina any other sources or even refractory erosion, these are the common entrapment sometimes you find only crack sometimes you find crack associated with entrapments; that means, the entrapment was possibly responsible and then crack has form. Sometimes you fine only crack no entrapment and crack means there will be some internal oxidation when they because one the crack comes to the surface some oxygen you know we will get inside. So, we will some get some scale, you will some get grain coarsening you will get some internal oxidation.

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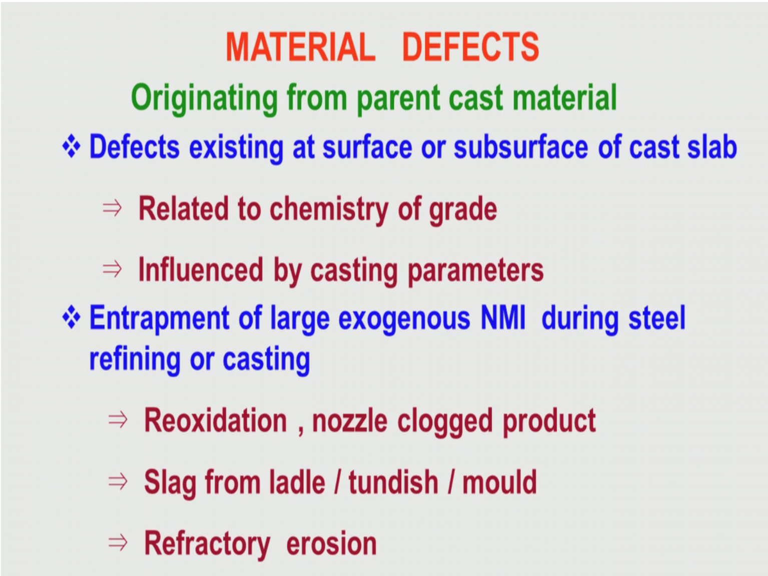

So, whether cracks are present on its own or cracks are present along with entrapments large entrapments that is what is important to identify what is the genesis of the problem. Now again I am telling this material defects what basically this course is related to material defects are not processing defect they are basically originating in principal from the parent cast material. So, defects existing either at the surface or subsurface of the cast product whether it is slab or bloom or billet, they might be related to the chemistry of the grade; that means, their location their formation I am not telling the chemistries is related directly, but what I am telling is the grade because of the particular grade certain type of defects are created.

So, that way the grade is responsible or they might be influenced by the casting parameters themselves. Some are grade specified grade related as I have told you, you know this laminations are basically coming from sometimes the surface lamination sometimes I have coming to from depressions I have told you, those laminations which are located near the edges there coming from certain specific locations; that means, person specific depressions which are originating from particular originating the particular grades like 0.1 percent carbon. So, called peritectic grade or 304 stainless steel the so called again peritectic grade in stainless family. So, there grade is playing a role because the delta to gamma transformation I have mentioned to several times is taking place are a crucial stage of solidification.

So, by slight adjustment of chemistry you can take care of this problem. So, here chemistry of the grade is that is why important, you can slightly adjust the chemistry and take care of this problem. And sometimes the problems are due to casting parameters as also; that means, suddenly there was a you know fluctuation in mould, suddenly there was a temporary suddenly there was a casting speed change, then it is due to casting parameters nothing do with the grade. So, grade great is important because grade we will dictate as I have mentioned earlier how the solidification will take place, where sticking will be there or depression will be there, if there is sticking then you have to tackle it in somewhere I have mentioned earlier. If it is depression you have to tackle with adjustment of chemistry with adjustment of mould powder. So, that you know the heat transfer is control heat transfer is uniform.

So, that way the grade is important, but casting parameters first you should decide on the grade, also casting parameter as such if there is some irregularity that might generate some defect. So, both are important that is why I am mentioning the defects existing at sub surface or subsurface of cast lab, it can be due to both name. Then another important source as I have mentioned here entrapment of larger exogenous n m I during steel refining or costing. So, this is one source another source is defect as such; that means, crack or lamination whatever. So, your central segregation central crack these are happening due to continuous casting.

But if there are large exogenous NMI; that means, if there is a re oxidation during secondary refining, if there is a entrapment of nozzle clogged product there is a problem nozzle clogged product is basically what aluminium mainly. Then slag I have mentioned several times the refractory erosion. So, these are all sources of exogenous entrapments or NMI which can create material defect. So, two broad categories either exogenous entrapments large or cast defect whether crack or you know surface other surface defects like deep oscillation marks and depressions these might create problem. So, two broad categories of material defects entrapments and surface, this cast product defects in cast product.

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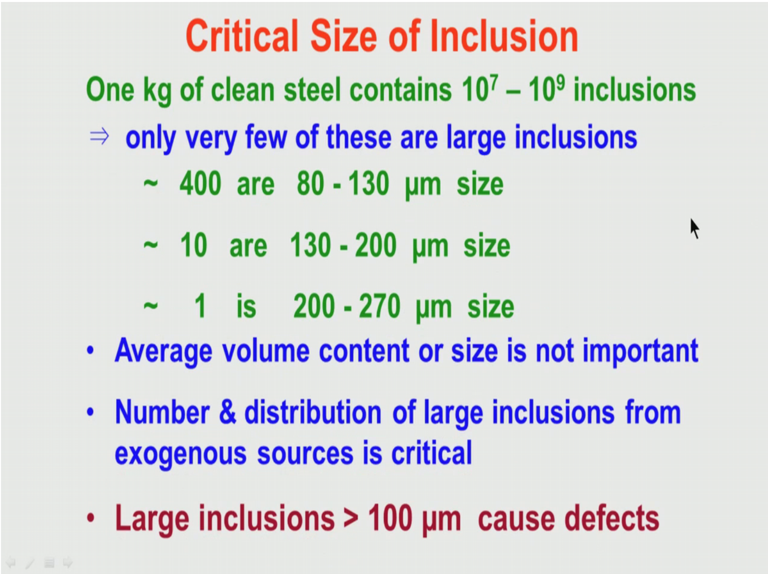

This I had mentioned one stage that critical size of inclusion is important because in steel any steel even in very clean steel you will find many small inclusions, we need not worry about small inclusions as I have trying to tell you. Because I have mentioned that one kg of clean steel they might contain very you see ten to the power 7 to 10 to the power 9 inclusions; that means, about one [FL] of inclusions you might find in one kg of clean steel, I have talking of a you know that is steel I am taking of clean steel. But fortunately most of these inclusions are very small which is call it benign; that means, less harmful only few or large say about 400 or about a 80 to 130 only 10is about 130 200 micron only one probability of such big inclusion is only one or less than one.

So, we have to worry about only large inclusions, which are very few in numbers, but there might be if large inclusions present they might create problem. So, inclusions as such is not a problem large inclusions and too much of large inclusion is a problem. So, average volume content of inclusion is not important, you might find you know one particular steel is relatively clean the volume content of inclusion is less point less then 0.1, but certain inclusions are quite large in size. So, we have to worry about that because those inclusions we will create generate defect. So, average volume content or average size is not important what is important is weather some large size inclusions are present or not.

So, number and distribution are large inclusions, they normally come from exogenous sources for endogenous sources; that means, de oxidation products they are normally smaller in size, but re oxidation; that means, when you know oxygen enrichment is taking place afterwards; that means, when steel is exposed during its transfer from say ladle tundish or tundish to mould, there is called re oxidation those are the inclusions which are large in size. Than you know I have mentioned what are the sources of large inclusion slag is there are normally.

So, large in size slag entrapment or entrainment the refractory erosions they are a large in size. So, we have to really worry about those large inclusions which are say 100 micron or more also 70 80 microns are more, these are the inclusions we have to be careful about and not very small inclusions.