Steel Quality Role of Secondary Refining and Continuous Casting

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Module – 08
Lecture – 47

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

In the earlier sessions I have talked about what are the type of you know defects in the cast product, and what are the sources of large entrapments in a cast product, then how we can control entrapments, how we can control the cast products those issues have been covered in quite details. So, this is very practical issues I will discussing now is identification of genesis of quality problems in steel products through metallographic investigation, like sometimes in spite of all our efforts or in in say if we are not very knowledgeable when you are doing continuous casting, in a particular aspect of casting we may not be knowing much then what happens in the product, in the cast product or in the final roll product or forge product we might encountered some defects.

Now, then the question comes where from the defect has generated that is very important; because defects have already taken place that is why it has come to the surface you know it has been identified. Now the question is how do you know what is the genesis, what is the source of the quality problem that is very important. So, how do you do that? So, I will be discussing regarding that in this session. So, metallographic investigation and proper inspection these are very important issues. So, that is why identification of genesis of quality problems in steel products, through metallographic investigation that is what I will be discussing in this session.

So, how do we do investigation that is very important. Suppose we want to identify what are the defects present sometimes defects may be so small or if you do not have proper inspection facility we may miss some of the defects. So, our job is to look for defects because you know then only you will know, what is the quality of the product. If we miss some of the defects because of you know inadequate inspection facility, then we will not be knowing where the defects were and where from the defects have come first we have to identify the defects then only we can set about going about the origin identifying the origin of the defect. So, inspection of the product, I am now talking of the you know not necessarily cast product even roll product because a cast products are finally, have to be rolled or forged then only it can be used for a particular application.

So, even if the product has been rolled or forged, then certain defects are coming to the surface or may be through ultrasonic defect you can identify some defect, then we should know where from the defects have originated whether they are material problems; that means, defects originating at the cast product itself or they have occurred during processing of the steel; that means, whether they are material defect or processing defect I have told you the defects can be up to broad categories. So, what I am harping on is identification of the material defect; that means, those defects which are originating from the cast product, that is the domain of our this lecture or you know this program.

So, anyway whether it is a cast product or you know final product what is important is suitable inspection.

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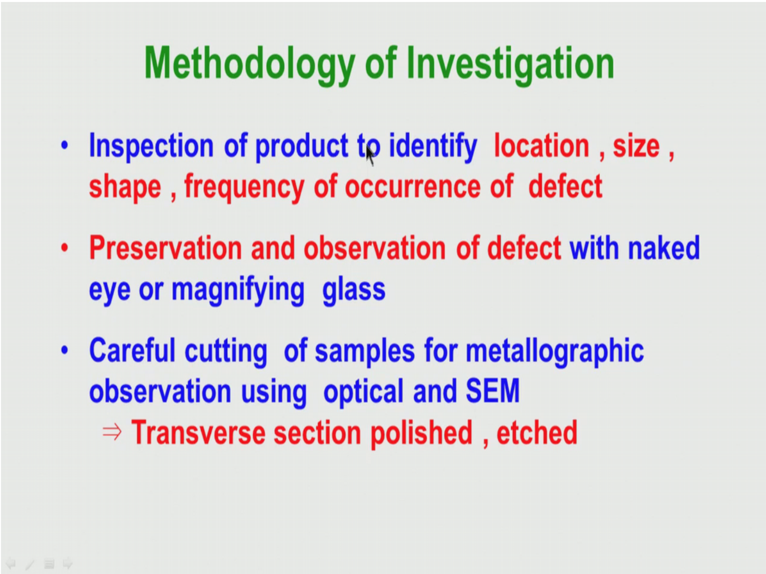

So, what I am mentioned is inspection of the product to identify. So, what we are going to identify whenever the location; that means, with respect to the product where does a defect lie; whether it is random, whether it is at a particular location near the edge, at the centre of the product this is very important. So, location size shape shape is also important. Frequency of occurrence of defect this is very important like one defect you know might be randomly located, there is no typical frequency of occurrence, but certain defects normally like you know in a cast product let us talk about oscillation marks. So, there is a standard frequency of occurrence that is not random, but the I have mentioned earlier that that by itself is not a defect you know, but if it is those deep oscillation marks if the oscillation marks are deep then there will they are constituted as a defect. So, this frequency of occurrence of defect is very important. So, we have to identify the location of the defect on the either to cast or in the final product surface whether it is a the near the corner off corner middle or whatever it is.

And then the size what is the size of the defect you must (Refer Time: 05:21) know what is the shape and the some of the defects can be as I mentioned earlier longitudinal direction; that means, in the longer direction of the casting say it is a occurring. So, or may be a transverse directions. So, again those are very important the shape, frequency again is important, then suppose a defect we have identify certain defect we must preserve the defect in the process of cutting sample for analysis of defect, we should not you know we should not make a situation that the defect is you know destroyed. So, that is why we are telling preservation the defect should be properly preserved where we have to be careful when we prepare samples, and then observation of defect. Normal eye and with magnifying glass may be sometimes the defect may be so, you know small it requires some magnifying glass.

And you know some of the industries particularly for the products they have very good inspection facilities; that means, it is a continue like for a h r coil hot roll coil I am talking about or a cool rolled coil. So, the whole coil that may be it can be uncoiled and you can see the whole surface about the top surface as well as the bottom surface, and you can identify at what stage defect is there. So, it is not with normal eye only, but with a glass with some magnification you can see. So, it is very important to have proper inspection facility. Now suppose we have identified yes there is a defect. So, we are also preserving the defect we do not we are not allowing the defect to simply go to vest then what we do? A small portion of the defect we are cutting samples from it. So, careful cutting of samples without destroying the defect at large may be one portion of it we I am only cutting and then we are preparing metallographic samples for optical or may be scanning electron microscope, I will come to it later on. So, what we do? We make it transverse section; why we do a make a transverse section? Because always we cannot see the defect whatever is present beneath the surface, we are seeing the defect only at the surface, but at the subsurface or even below that there might be some components of the defect that is very important, like I am given you example we might see some depletion on the surface whether longitudinal or transverse on a cast sample.

But if you do not cut we do not go to the transverse session sub surface, we do not find then there may be crack beneath those surface. Like you know oscillation marks I have told you if you have a deep oscillation marks, we are seeing the only the deep oscillation mark on the surface, but beneath the surface below the surface we might find there is crack there may some entrapment mould powder and there can be many issues. So, you must take a transverse section wherever we are finding a defect we must cut the sample small area of the sample when another other area should remain as it is. So, that may be in future also we can do cut the surface or the defect. So, we have to take a transverse section and then we polish the section etched the section, because sometimes you have to see look at the polished surface transverse section, like if you have an metallic non metallic inclusions or large entrapments even fine inclusions. So, maybe you have to see at the polished surface itself, but sometimes for identifying the different phases you have to etch it.

So, first you look at the polished surface after you polish it in a nice way, and then take photograph preserve it and then etch it, and then again look at it what about the phases and constituents are present.

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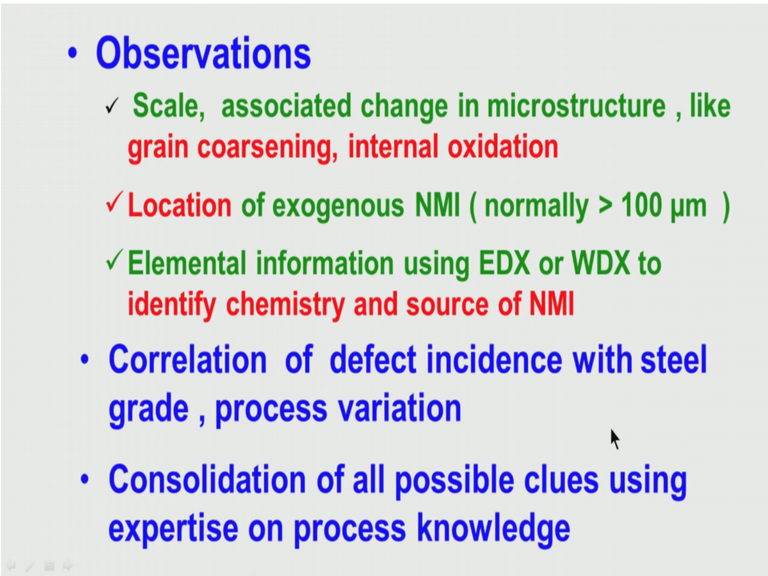

So, at every stages we have to be very careful that is first important, then what do you observe. So, we have taken a, we have identified a defect we are taken a sample and we have taken a section also transverse section and what do you observe under optical microscope that is very important. So, first we observe whether the scale is there, sometimes you know when there is reoxidation taking place. We always find there is a scale; that means, there will be some oxide there is we called it scale may be iron oxide may be some other oxide, but the scale has to be properly identified what is the size of the scale what is the depth of the scale, and then what is the associated change in microstructure? You see normally we know that what should be the microstructure or the cross section, but if there is a defect the microstructure might have changed in that particular area in the localized area. So, that is why it is important to see the microstructure also near the defect. So, you see the defect area you see the area which is adjacent to the defect, and identify what is the change in microstructure when there is no defect what is the microstructure; that means, away from the defect what is the microstructure near the defect what is the microstructure, then only you can identify what is the difference in microstructure that is been caused by the presence of the defect. So, if there is a scale the you know adjacent microstructure will be different, you know there may be yes there may be like grain coarsening. When normal grain size away from the defect might be something, but near the defect you might find there may grains have coarsened.

So; that means, grains have coarsened means those particular area has been expose to high temperature relatively high temperature. So, why it has been exposed; that means, if there was scale there might be decarburization. So, there might be internal oxidation; that means, identification of grain coarsening, identification of internal what does internal oxidation mean? Any interior surface of a product is not suppose to be oxidized the surface will be oxidized because surface is exposed to high temperature, may be during reheating, may be during continuous casting, may be during rolling, but if the internal surface; that means, in the you are seeing at the cross section near 35 there is some internal oxidation what does it mean? That means, that defect has got exposed at certain stage, then only there can be internal oxidation surface oxidation can be explained, but why there will be a oxidation at the interior of a product? That means, there must have been certain exposure of the defect zone.

So, that is why scale has formed, that is why internal oxidation has formed, that is why grain coarsening has taken place. So, these are all indications that there has been some exposure of that area either there was crack. So, that readily has got exposed or there was some large entrapment and during you know hot rolling or hot forging the formability of that defect and the formability of the matrix are different. So, at the interface there are might be crack formation.

So, if the crack formation is there and it gains the if crack formation is there and it gets weld it does not come to the surface there is no problem, but if the crack formation comes to the surface during welding or forging then it is a problem; because then there will be oxidation there will be scale formation and you know other problems associated problems will be there. So, observations under microscope is very important that is why I am harping on it. Then we look at a non metallic inclusions if we have large non metallic inclusions which are more than 100 micron, you can see it with normal eye itself you know normally I will give you some example where certain lamination defects you can already see with normal eye on the roll surface.

So, those are basically associated with large exogenous entrapments, but if there are smaller inclusions then you will you have to look at you know under the microscope. So, what are the location of the inclusions again these are very important. If the genesis of the crack is inclusion or large inclusion exogenous NMI then that crack and that NMI are normally found together; that means, the crack has started forming at the location of the big inclusion exogenous has non metallic inclusion.

So, this location of inclusion whether it is away from the defect or it is near the defect again that is important. You know all (Refer Time: 14:18) I have mentioned and a I will again mention you will find numerous small inclusions, those are not a problem those do not constitute a problem always. But if we have a large inclusion if we have high density of inclusion that is many inclusion then there may be a problem then there might be a crack formation. So, that is why location of this inclusions and particularly exogenous has entrapments, particularly large entrapments where they are present, if they are present near the crack or away from the crack those have to be identified.

Then I have mentioned we can do under scanning electron microscopy if we have attachment of EDX or WDX. EDX means energy dispersive analysis of x rays, WDX means wavelength dispersive analysis of x rays what does it do it basically whenever a putting the sample under the scanning electron microscope. So, electrons which are you know impinging on the sample. So, what our elements are present in the sample they will generate characteristic x ray, they are called characteristic x ray because all elements suppose we have iron, suppose we have carbon, suppose we have manganese, suppose we have silicon, all this elements have definite wavelength definite energy of x rays which will emanate. So, electrons are impinging on the sample. So, depending on whatever elements are present in the sample different x rays of different wavelengths and energies are getting generated. So, our job is to analyze is to detect those x rays either from their energy or from their wavelength, wavelength and energy are interrelated. So, you can either identify their wavelength and detect them or you can identify their energy and detect them. So, the detector is either based on their wavelength or based on their energy. So, that is why it is call either energy dispersive x ray or wavelength dispersive of dispersive x ray.

So, the detector is different for detecting the wavelength or the energy it does not matter whether we are detecting energy or wavelength, what is important is we have to identify that particular energy or wavelength and from there we can know what is the element that is what is important. So, basically we are identifying element we are getting elemental information we might get a you know scanning image of the particular element how silicon is present in a particular area. If we have a silicon oxide inclusion in a sample, you can particularly see where silicon is present wherever we come to the inclusion we have very high silicon because it is SiO_2 or we might get a alumina inclusion. So, they are aluminum will be very high. So, we can image aluminum or silicon or iron and we can identify where those defects are or inclusions are present.

And we can also analyze at a particular location; that means, in the matrix we can analyze what are the elements present, in inclusion in a defect area we can analyze what are the elements present and from there also we can identify whether what is the source what is the chemistry of the defect, whether the inclusion is alumina alumina silicate or a SiO_2 or nitride or even carbide which type of nitride, which type of oxide all these are possible to know. Like I have mentioned to you that slag entrapment is a typical exogenous entrapment, now slag can be from ladle slag can get entrap from the tundish slag can get entrap from the mould slag. Now hoe to distinguish? You can distinguish from their chemistry slags from ladle is different having different chemistry it is more (Refer Time: 18:15) in calcium oxide slag from tundish it has some amount of silicon silicon oxide because you know you are using a duplex slag there (Refer Time: 18:26) is there at the top. So, (Refer Time: 18:29) has lot of silica. So, SiO_2 content of tundish slag is more than say ladle slag or mould slag. So, you can know from the analysis whether it is ladle slag mould slag or tundish slag then moild slag, has you know fluoride calcium fluoride or it has normally some sodium oxide. So, you can identify the source of the defect source of the exogenous entrapment from the analysis, this analysis done in a cm by EDX or WDX these are small you know locations you cannot do normal chemical analysis.Normal chemical analysis what will it give you it give you information from a large area. So, that will not be adequate. So, we want to analyze a localized area in a under the microscope scanning electron microscope, that is why EDX and WDX attachments in a cm is important for localized information for getting information from petty small areas, for inclusions for entrapments this is the whole idea of analyzing it.

Normal chemical analysis we give you from the large area information coming from the large area, x ray florescence you are getting information from a large area, but from EDX and WDX attachment in acm you are getting information from small area this small area of the micro you know micro graph or small area of a micro constituent, small area of an inclusion, small area of entrapment all this can be analyzed. So, this is very important. So, basically from the elemental information we can identify the chemistry of the NMI that is what is important. From there if we have prior knowledge we can know what are the possible source of that entrapment now then what we do? After you do all this observations we correlate the incidence of defect not only what about constituents are there, but what are the as I was telling what is the frequency of the defect, what is the location of the defect and then I have told you in earlier sessions (Refer Time: 20:43) we broadly understand from the great chemistry how it will behave during solidification.

So, this correlation of defect incidence with steel grade and process variation is very important. So, we know what is the steel grade. So, from that if we have prior knowledge. So, we also know what type of defect is expected. So, whether it is really. So, we can correlate. So, correlation of defect incidence with steel grade what is process variation; that means, during continuous casting at what stage you know any defect is taking place? Was there a variation was there a sudden fluctuation in a casting speed that is very important, what was the mould level fluctuation again these are all possible to identify in an modern casters. So, we you know at what stage of casting this variation had taken place, and you try to correlate whether defect is coming in the product at that stage or not. So, all this correlation is very important. You should not remain in the dark. So, one defect has come you try to analyze it blindly, that is not the right way of analysis right way analysis is try to correlate this defect with the steel grade with the and if you know the steel grade you know what is the possible called circulation characteristics whether it should indicate a shell type of defect; that means, whether it the characteristic was you know sticking type, whether it was a depression type, if they has a depression whether there was a crack. So, we know from theoretical understanding what are the possibilities.

So, now you correlate your knowledge with the actual observation sometimes you are knowledgeable, but we do not have all this observations sometimes we have the sample so; that means, we know the observations, but we do not know we have no knowledge. So, what is important is correlation of this theory and practice, correlation of knowledge with observations then only our knowledge will be very specific and we can identify we can know what is the source what is the genesis of the defect. This is very important during any analysis of defect any analysis of observations and then after you try to correlate then you consolidate all possible clues, from observations you are getting clues, from correlation you are getting some clues (Refer Time: 23:10) there was some you know abnormality in the casting process, there was some abnormality you know when you are doing some secondary refining, at that stage we have to know whether there was any correlation process. There was any defect in the process defect means there was some abnormality in the process may be for a you know when you degaussing at in vacuum suddenly the vacuum level went wrong suddenly the vacuum level changed. So, you know at what stage it happen. So, that particular heat might be having problem during continuous casting it can tell it can correlate at what stage of casting; that means, not necessarily in the heat wholly one certain stage of the heat of the casting, some may be problem was there.

So, all these are really important correlation. So, what I am telling here is consolidation of all possible clues these are clues observation is a clue and a defect or process variation is a clue. So, try to consolidate all possible clues using expertise on process knowledge again this is a important. We should not be blind about the process product quality is a outcome of process and chemistry. So, whatever is happening in the quality front is because of some process irregularities or because of sudden new chemistry problem. So, because of that it has happened, it just like that any defect cannot happen. So, that is why consolidation of all possible clues using expertise on process knowledge, can only identified specifically what is the possible reason of a defect generation this is very important.