Steel Quality Role of Secondary Refining and Continuous Casting

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Module - 04
Lecture - 20
Quality of Cast Product

When I started this course, then I had mentioned that this course basically covers quality issues of material origin. That means, the sources which are based on the material not on the processing, which are causing quality problems. So, I will be I am covering those aspects in this course.

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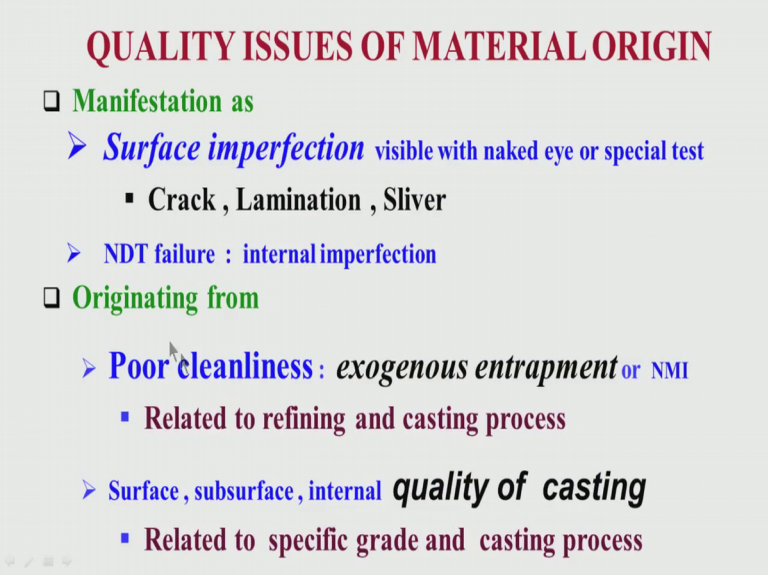

Now, I had mentioned that basically there are two broad origins for this quality problems, one is the poor cleanliness. That means, exogenous entrapment or nonmetallic inclusion they related to they are related refining and continuous casting stages. Continuous casting ingot casting, but I am covering in this course mainly continuous casting.

So, the poor cleanliness is one major source of exogenous entrapments, and then how it causes problems I have covered different processors the basic ideas of you know quality issues and they are it has been discussed that exogenous entrapment particularly the

larger ones they are a very importance source of the poor cleanliness and therefore, an important quality issue.

Now, there is another important origin of quality issues that is basically the quality of the continuous casting. These are the exogenous entrapments which are you know taking place during refining or casting process, but now I will start talking about the quality of the casting, what is meant by the quality of casting? Basically it may be at the surface of the casting it maybe at the sub surface level or it may be internal position of the casting.

Why this is important? Because the casting when you are we have to finally, roll it hot roll it subsequently may be cold roll it or you have to hot it. So, during that processing whatever quality problems are there, whatever you know cracks or sub surface cracks are there internal cracks are there they might come to the surface. So, that may constitute an important quality issue.

So, today and you know on subsequent presentations I will be talking about quality of casting what are those and the different issues of that. So, this quality they are related to specific grade and casting process there are two issues. One is the grades steel grade which you are casting that is important because certain quality issues are inherent to the specific steel grade and some are basically related to the casting process as such. So, both are important, you have to keep in mind that for the steel grade as well as the casting process.

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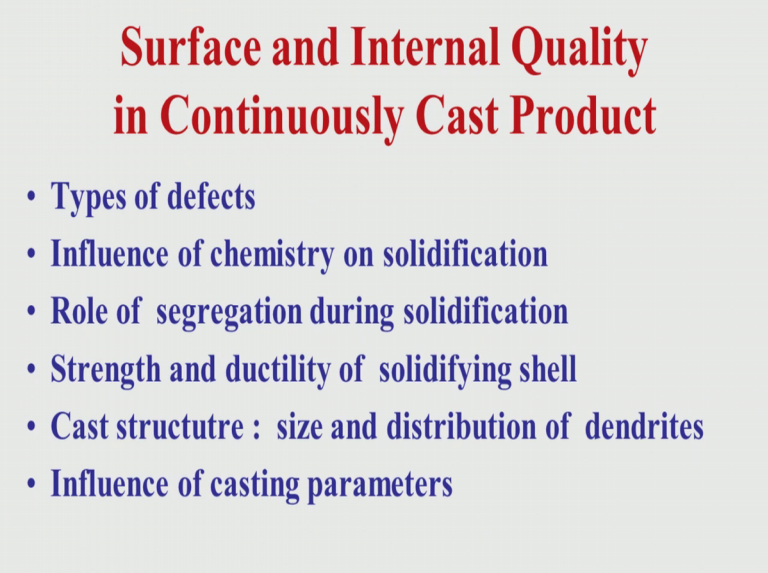

So, let me start with this you know quality issues in continuously cast product. So, it can be surface it can be internal quality as I was mentioning. So, now, what is important what I will be covering is what are the types of defects, what are the type of quality issues influence of chemistry on solidification as such. Why chemistry is important because it controls the solidification sequence, how solidification takes place what are whether it is delta or it is gamma, at what temperature delta gamma transformation takes place all these issues.

Then another very important issue is that segregation. You know why segregation is important during solidification, how it is related to the quality problem, this will I will be trying to discuss. Then another important issue is the strength and ductility of solidifying shell when steel is being continuously cast, solidification takes some time it does not you know occur instantaneously.

So, during the stage of solidification the solid shell is forming in between there is a you know mushy zone; that means, solid plus liquid and then there is a liquid. So, the shell is one aspect then there is a mushy zone and finally, the liquid. So, this is what is the strength and ductility of the solidifying shell this also I will discuss. Because this is very important to understand, because at what point of time, at what temperature, at what stage of solidification cracks will start developing whether cracks will start developing even after solidification during the time of cooling this is very important. So, strength and ductility of the solid shell is very important.

Then I will be talking about the cast structure; cast structure basically means dendrites all of us know that we have we will be talking about the dendritic solidification; that means, what is the size of the dendrites, what are the distribution of dendrites, what is the you know different zones of cast structure whether it is equiaxed, whether it is columnar what is the size relatively relative fraction of columnar vis a vis you know central equiaxed all these issues are very important because, if you do not understand that we cannot know why cracks will form, at what stage crack will form whether they are at the surface whether they are at the sub surface location or whether they are interior at the you know central portion of the casting all these are important issues.

Then of course, influence of casting parameters. That means, casting speed you know super hit these are very important issues. You know what is the type of powder you are

using that gives us what is the you know heat transfer in a mould, the primary cooling, primary cooling takes place in a mould continuous casting mould. So, the continuous casting you know parameter rather the powder which you are used which will get melted and finally, the slag is generated mould slag. So, the mould slag will finally, determine the heat transfer characteristic for the primary cooling. So, that is very important.

Then the secondary cooling means when the slab or bloom or billet is coming out of the mould. So, below the mould it is a secondarty cooling we call it is there is a direct cooling by water or mist air mist. So, there in the secondary cooling what should be the cooling intensity, whether it should be more or less; what is the uniformity how does it come down. So, all these are very important issues as far as quality of the surface and internal you know portion of the cast product is concerned.

And now why cast product is important; because after all the cast product will be rolling will be forging it. So, finally, whatever product we get, the final quality in the product will very much depend on the quality of the cast product. So, that is why you are interested in the quality of the cast product.

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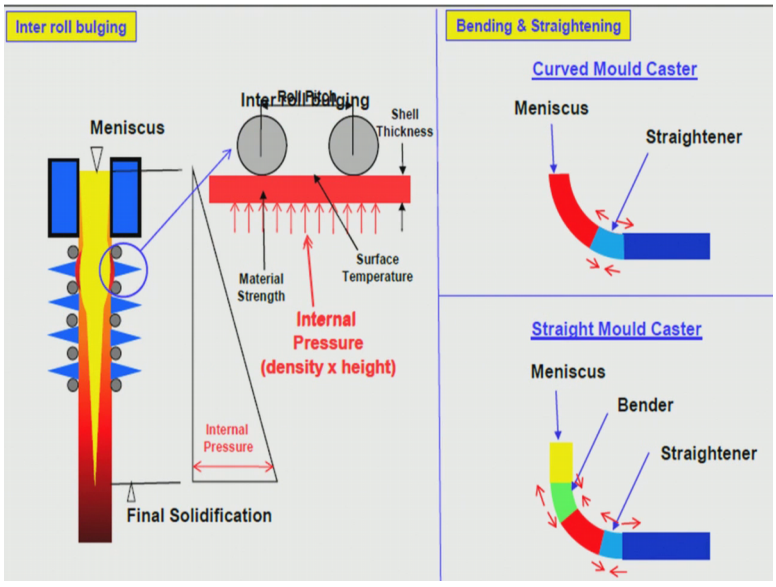

Now, let us try to understand what is happening during continuous casting. This is very important to understand. I think first this areas is called the mould these are water cooled mould and we are loading the liquid steel from the tundish to the mould inside the mould. So, this surface level is called the meniscus, what you can see you cannot see this

portion of the all the casting is taking place you can see only the meniscus which is the surface. And liquid steel on top of that you have as I have mentioned in earlier session we have molten slag, which we call mould slag and on top of that is the powder from which the powder melts and the slag is generated.

So, here first the powder on the top of it beneath that it is a may be solid liquid stage, semi molten powder and beneath that below that is a molten slag and afterwards still below of course, is the liquid steel. So, this liquid this yellow portion is the liquid steel here, and then the solidification starts just below the meniscus itself because there is cooling there is a heat transfer is taking place within the mould. So, heat is getting extracted this way, the mould is water cooled that means, heat is taking is getting extracted in the horizontal direction.

So, as you are coming down the solid shell this grade portion is a solid shell that the width of the solid shell thickness of the solid shell is increasing, as you are coming down. That means, lower we go in the casting direction thicker is the solid shell, which is expected because you know mould and mould solidification is taking place in the mould therefore, the solid shell is increasing in thickness this is important. And then when it is coming below the mould; that means, when it is coming out of the shell is coming out of the mould then what is important is the shell thickness is very important. Otherwise you know there is a ferrostatic pressure this is liquid, this liquid will put lot of pressure on the solid shell.

So, when there is a mould, mould is the support for the shell, but when the shell is coming out of the mould, what is the support? There has to be some support. So, there are rolls these are the rolls, which give the support for the shell to the solidifying strand both the sides. So, the support of mould is support of rolls support from the rolls these are all moving rolls, you know there are static rolls they are moving rolls which also gives an you know vertical downward velocity to the shell, that is important to the strand. Strand means everything; the shell in the mushy zone as well as the liquid this whole thing is called strand, this one is the solid shell then your mushy zone this I will be coming one after another and then you have liquid. So, this is very important.

Finally as you are coming down after certain distances, the whole solidification is over. So, this is the final solidification location. So, solidification is starting in the mould

where there is primary cooling, these are copper moulds and these are water cooled. So, heat flow heat direction is taking the you know heat which is inside the liquid steel away from this, this direction horizontal direction.

We are assuming that there is not much of heat flow in the vertical direction because why? Because you have a slag here and on top of that you have powder. So, we are assuming that heat flow is taking place only during the horizontal direction. So, that is why you know the solid shell is increasing in thickness as you are coming down.

Now, the below the mould again the solid shell is increasing, but here there is a possibility of solid shell solid shell getting bend because there is not much of support as you not continuous support, and a solid shell strength is also important here you know how much bending will take place all these arte important and in between these rolls we have water spray; this is the water spray here, here in between the rolls. It may be water it may be mist air mist; mist is basically combination of air and water.

So, this either water cooling or mist cooling this is known as the secondary cooling; primary cooling is occurring inside the mould below the mould it is called secondary cooling. So, certain amount of water or mist is necessary. So, how much of water. So, what is the cooling intensity that is very important because at what point you want the final solidification is dictated by how much of secondary cooling you will be using. What is the intensity of secondary cooling? What is the intensity here what is the intensity down because as you are you know going down; that means, you are requiring less cooling because you know here high amount of liquid steel is there as you are coming down more of solidification is taking place. So, you require less and less cooling.

So, cooling intensity is very high here secondary cooling intensity, less here lees here coming down as you are going down. So, this is very important now I have mentioned here you know this look at this, this is what is known as ferrostatic pressure is given by the liquid steel, so what about liquid steel is inside the strand inside the caster that will put ferrostatic pressure on the shell solid shell which is forming.

So, the pressure is zero here, as you are coming down pressure is increasing. So, after solidification is complete there will be no pressure of course, because there is no liquid. So, this is the indication solid, the pressure is starting from here and it is increasing till solidification is over; this is called ferrostatic pressure this ferrostatic head is increasing.

As you are coming down the head is increasing. So, pressure is also increasing this also plays an very important role in continuous casting. So, on the solid shell there is ferrostatic pressure this is very important to understand. Now look at here this is this portion which has been put here. So, this is the shell thickness on shell there is internal pressure which is called ferrostatic pressure, whatever is shown here.

So, the pressure is dependent on the density and the height. Height means this is the height as you are going down the pressure is increasing. So, that is what is important and the material after all what is this solid shell. So, the material properties the high temperature property of the shell is very important, this we will discuss in details.

Whenever solidification is taking place how the solidification will take place it depends on the chemistry of the steel. It may solidify through delta it may solidify through delta plus gamma or through gamma; that means, it may solidify through delta ferrite, it may solidified through austenite depends on the chemistry all this I will discuss in detail. So, you will come to know.

So, what is important is the property of the shell is very important property of the shell is dictated by what? Dictated by whether it is delta or gamma or delta plus gamma or what is the shell thickness, whether it can resist the internal pressure this is very important. So, material strength is important, surface temperature is important, because as the temperature is coming down the strength also will change the ductility will change toughness will change. So, temperature is important whether it is delta or gamma that is important and internal pressure is important like as you are going down pressure is increasing. So, all these are important issues during continuous casting.

So, the distance between the two rolls it is called roll pitch, this somewhere this is not coming out very clearly, but is called the roll pitch that it is the distance between the rolls is called roll pitch it is not uniform. As you are coming down you know the shell is increasing shell thickness; that means, you do not require so much of support, here you require more support. So, the pitch will be less, as you are coming down pitch may not be required so much because you know always the shell is right thick too much or it can resist the pressure. So, too much of support may not be necessary. So, these are all important issues.

So, now this I had discussed earlier, that there can be two types of mould this I discussed with respect to the you know distribution of the inclusions in mould, but here try to understand what is happening if you have a straight mould. The mould has to be first bent and then it has to be again straightened. To make it here it is vertical finally, you want this shell solid shell should become horizontal. We are showing only the vertical portion here actually it is not vertical; it is trying after below the mould it is slowly bending. So, that is what is important you have to bend it the strand has to be bent. So, first bending is necessary because it bender.

So, when we are bending try to see what is happening here, this is the inner radius I have mentioned earlier. So, this inner radius portion is having a what type of stress? It is a compressive stress here outer areas during the bending this is the tensile stress. So, you just see this is not uniform because of the bending. Everything was uniform and it is vertical again everything will be uniform when it is horizontal, but if the process of bending inner radius this is the inner radius of the caster there is a compressive stress on the shells in this portion there is a tensile stress and in between there is no stress at all.

And then first there is bending if you have a curved mould there is no bending because the strand itself is such that you know the mould here the mould is vertical, but here if the curved mould is here; that means, the mould itself will be curved. So, the shell which is coming out of the mould is in bent, is not vertical like here. So, there is no bending necessary additional because the bending has started in a mould itself.

So, what is necessary here is straightening. Here straightening is necessary here also straightening is necessary because finally, it has to be made horizontal otherwise what will happen? It will go on like this if you do not use straightener then what happens this mould will get like this, it will bend like this because it has started bending here you have given a bending.

So, mould will be like this, to make it you know horizontal some straightener is necessary. Straightener means you have to put some additional pressure here so that it becomes horizontal. So, while bending inner surfaces becomes or gets compressive strain, but during straightening here the inner surface layer is getting the opposite it is getting here it is compressive, here it is not here this outer portion is compressive, here it is a increasing in the this direction.

You just see that reverse. So, what is important is try to understand that the shell is getting lot of mechanical strain during solidification, it is unlike ingot casting. Ingot casting it is shell after it has solidifying there is no additional strain, the shell is not moving it is static here the shell is moving solid shell, solid shell which is forming inside the mould it is not static it is coming out it is in continuous movement still the whole thing gets solidified.

So, a portion of it is getting lot of mechanical strain that is important. Inside you are getting lot of internal pressure ferrostatic pressure, then the shell during solidification there will be some there will be some you know what is that called when you when the solidification take place there is shrinkage. When delta to gamma transformation takes place again there will be shrinkage, when the temperature of the shell is coming down again there will be thermal stress. So, the shell is undergoing lot of stress I will discuss in details everything.

So, what is important to understand is that the solid shell is not static, it is under movement it is undergoing lot of stress, there may be ferrostatic pressure, from the liquid steel during bending, during straightening, and there are lot of pressure on the surface on both the surfaces. This pressure this tension or compression here it is you know tension at the straightener, this tension and at the outer surface it is compression and in between it is nothing you know internal stress is basically in between there will be balancing one another.

So, tension at the inner surface compression at the outer surface in between there is nothing. So, we have to understand for a straight mode situation is more complicated because first there is bending and then it is straightening, for a curved mould there is only straightening. So, relatively less internal stress here, but nevertheless there is internal stress at the surface at the both the surfaces the nature of stress will be different.

So, what is important is to understand the shell is undergoing lot of pressure, lot of stress, lot of strain. So, the property high temperature property of the shell solid shell is very important it should withstand all those strains, otherwise there will be crack formation that is what is important to understand.