Steel Quality Role of Secondary Refining and Continuous Casting

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Module - 04
Lecture - 21
Role of Concast Process, Caster Design and Steel Grade

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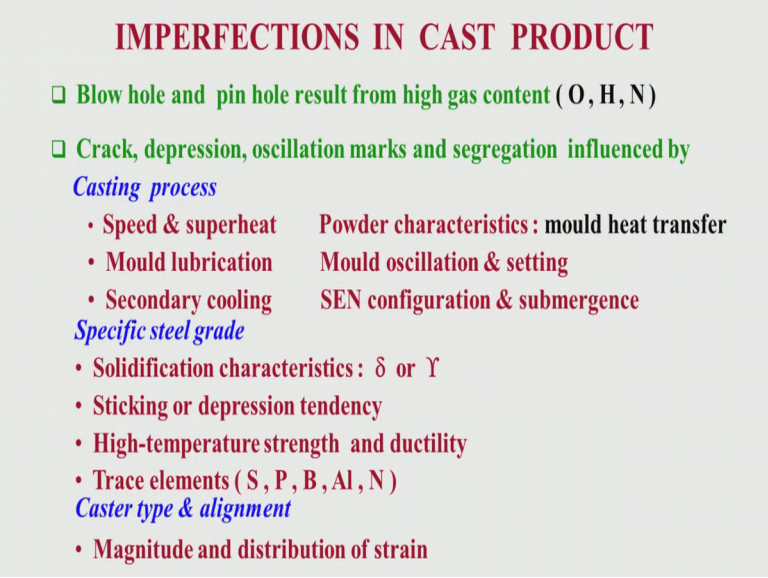

Let us try to get into the details what are the types of defects which are possible in a cast product. First is there may be blow hole or pin hole, we know that they result from high gas content. Now what are their values and all I will be discussing in details gas content means it can be oxygen, it can be hydrogen, it can be nitrogen. Oxygen, hydrogen, nitrogen, these are soluble in liquid steel, but when they come out of the steel they come out in the form of gas. So, unless their content solubility content is limited in liquid steel I have mentioned earlier how do you reduce soluble oxygen liquid steel you have to do deoxidation you have to do killing. How do you reduce hydrogen and nitrogen in liquid steel, you have to do degassing in secondary refining?

So, all these processes control the amounts of solutes oxygen, hydrogen and nitrogen in liquid steel. If they are beyond certain levels I will come to that you can find out to what extent the formation of you know pin holes or blow holes will be there. Everything depends on the value of this solutes, amount of this solutes in liquid steel at the time of

casting. That is why I had mentioned that when you are doing say primary link steel making your dissolved oxygen is as high as may be 500 or 600 p p m.

Now, if you want to cast that steel, your steel will be like a strainer; because so, much of oxygen is there dissolve oxygen they will all try to come out as gas, why it will come out, because the solubility of oxygen is quiet high in liquids steel, but much less in solid steel. So, where will it go it will it try to come out as gas. Therefore, oxygen hydrogen nitrogen contained in liquid steel has to be controlled before you do any casting otherwise you will have blow holes and pin holes. So, this is important, this is one type of defect which is there is a possibility.

Then there may be crack formation this is very important. You know when the solidification is taking place; the shell might develop some cracks. As I was telling the shell has certain properties it is at high temperature with finally, slowly coming down to the low temperature. So, at high temperature what is the strength, what is the toughness of the solid shell whether it is delta, whether it is gamma? Delta gamma they have different properties at high temperature. So, these are important whether they can withstand all those stresses, all those pressure ferrostatic pressure from inside liquid or you know at the surface of the solid shell there are lot of pressures as I have mentioned during bending during straightening.

So, whether the shell can withstand those stress or strain that we will finally, decide whether there will be crack formation or not in a solid shell. Then there may be a depression on the cast surface, I will come to it later on why depression will form. Depression basically means the surface is not uniformly flat, certain portions of the surface will have certain undulations depressions it is depressed certain portions of it. So, that is called depression these are defect, we do not want that we want surface to be more or less flat.

Then we may have oscillation marks, I have mentioned that unlike ingot casting continuous casting mould is not stationery this look at this, this is the mould.

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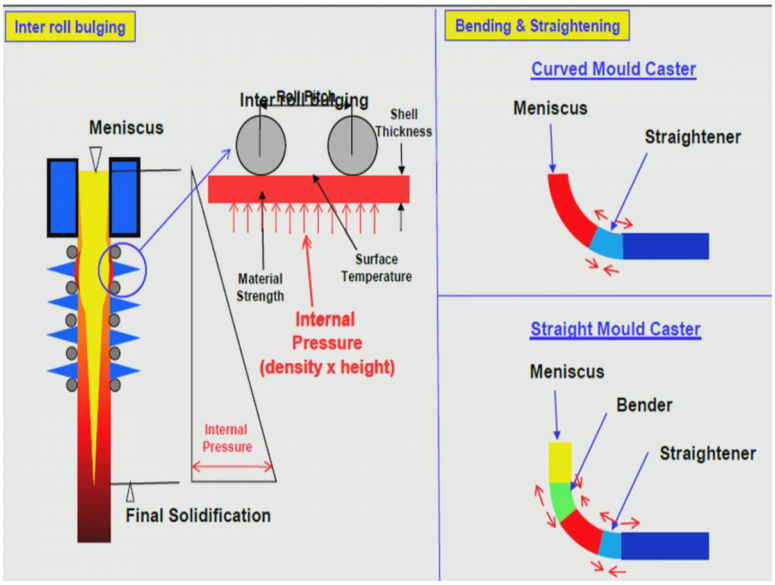

So, this mould is oscillating it is going up and down vertically, continuously during continuous casting. I have mentioned why it is necessary. Because otherwise there is a possibility of this shell getting stuck at the mould surfaces sticking problem will be there. So, for that you always require mould to oscillate, there is a frequency at what frequency it is oscillating, to what extent it will oscillate there is a amplitude also for the oscillation. So, this is very important, you cannot do any continuous casting without any mould oscillation.

So, now when you are oscillating the mould because of the oscillation nature there will be certain you know marks oscillation marks on the surface of the cast product, these are called oscillation marks. If the depth of the marks this oscillation marks are not very high; that means, it is not deep marks then it is we do not call it a defect. But then the oscillation marks are deep then it is a defect because it can create lot of problem. If the oscillation marks are deep then try to understand what is going to happen, again let us come back to here.

Suppose we have a oscillation marks on this or in the moulds suppose there is a oscillation marks, because oscillation marks are forming here itself, you know mould itself they are forming because the mould is oscillating. So, if the marks are there; that means, what happens? There is a air gap in between. So, sort of there is sort of heat transfer change, heat is getting extracted from inside to this way outside.

So, if there is a air gap formation because of the deep marks deep oscillation mark. So, those areas heat transfer will be relatively less, and we know that what the role heat transfer plays in solidification. Because the size of solidification structure size of the dendrites depends on the heat transfer. If the heat transfer is high dendrites will be smaller in size, which is desirable we do not want a core structure, we do not want cores grains. So, that is depended on the cast structure you know the size of the cast structure whether the dendrites or you know final grains, they depend on the heat transfer. So, heat transfer is going to be very important here.

So, if there is deep oscillation marks heat transfer is in those areas will be low the cast structure, those areas will be cores which is undesirable number one. Number two there might be because of these there might be cracks under those deep oscillation marks. So, those are undesirable. So, what are undesirables blow holes pin holes undesirables, cracks are undesirable, depressions are undesirables, deep oscillation marks are undesirable fine oscillation marks may be there that is not a problem, but if it is deep there is a problem.

Then, another important issue which is directly related to the quality of the cast product the segregation. Now what is segregation this again I will be discussing in details segregation of alloying elements or solutes in iron, you have carbon, you may have manganese, you may have silicon, you may have phosphorous, you may have sulphur, you may have oxygen, you may have hydrogen, have nitrogen all are solutes.

All solutes will segregate during solidification solidification means partition because the solubility limit of solid and liquid are different. For all these solutes solubility limit is solid is less compared to the liquid. So, what happens when solidification is taking place there is a movement of alloying elements from solid to the liquid, why? Because the solubility in solid is less solubility of oxygen, hydrogen nitrogen, carbon and all these alloying elements will be less in solid compared to the liquid. So, liquid will move from solid to the liquid phase, there is a combination of solid and liquid when solidification is taking place.

You know whenever solidification starts, this is a phenomena segregation is starting at that point and it will end only when the solidification is complete. So, segregation basically means preferential movement or transportation of alloying elements or solids

solutes carbon, sulphur, phosphate, oxygen, hydrogen, nitrogen any element you talk about. The extent of solubility is different extent of movement will be different, that I will be discussing in detail, but there has to be segregation solubility in solid is always less than solubility in liquid. So, segregation will always be there.

So, hence what is happening? The liquid is getting more and more rich in the solutes try to understand what is happening in, if there is segregation there will be segregation during solidification. So, the liquid which is remaining is getting more and more rich. So, what is happening? The portion of the liquid which will finally, solidify in the later portion of solidification they are having high amount of segregated liquid; that means, they are rich in the alloying elements. Therefore, there will be more of segregation in those portions.

The solid which is forming at the beginning of solidification they are relatively purer as with respect to the solute contents, but the solid which is forming at the later portion. So, they are having more segregation, more impurity that is why if you look at a cast product, if you look at the section of a cast product, you will find the center portion is most you know segregated. Center portion has more of carbon more of all alloying elements. So, we have to be careful about that you cannot escape this, but only thing is you have certain controls so, that the segregation level is relatively less, some parameters continuous casting parameters will lead to less of segregation that is what is important.

Now, all these you know cracks, depressions, oscillation marks, segregation they are depended on three issues major three issues first the casting process as such. The specific steel grade as such or the caster type as I have mentioned you know whether it is a vertical mould or you know curved mould that is called a caster type what is the radius of the caster all these will finally generate the magnitude and the distribution of the strain the caster type of alignment will give the relatively what amount of strain on the solid shell.

Now, what is casting process? We know continuous casting will take place at a certain speed, that will you know determine to what extent solidification will take place, what is the movement of the solid shell, how fast solidification will take place all these depends on the casting speed. And another important parameter is the superheat, the heat of the liquid which is being cast what is the temperature of the liquid steel with respect to its

liquidus, how much more it is that is called superheat this is very important. I will come to it also later on what is the effects of speed and superheat these will have effect on the cast structure.

Then what is the powder characteristics? Continuous casting two issues are very important, one is the mould oscillation which is necessary another is the powder which are using for casting. We cannot we do not have any continuous casting whether you are you are not using any lubrication. So, lubrication is given by what? Either it is a powder or by oil. Normally for small billets we have a oil you use oil as the lubricant, but for most of the other cases even for you know thicker billets, for blooms, for slabs for other you know (Refer Time: 13:11) casting you always have powder as a lubricant.

Powder will melt it will generate slag, more slag which will get inside you know it will get where does it getting? You get inside the mould. Inside the mould means at the interface between the mould and the shell it will gets inside here. It is melting here at the top you are adding powder at the top, powder is melting, slag is forming, slag will be just above the liquid steel and because of the oscillation that is another important requirement oscillation because of the oscillation some amount of liquid slag will be pushed inside here at the interface between the mould and the solid shell that helps in lubrication, that helps in prevention of you know sticking. Otherwise the there is a possibility of the solid shell getting stuck on the mould surface which is not desirable.

So, lubrication is an important requirement, it is given either by the powder or oil. These days mostly powder is used at the lubricant, and this powder characteristics; powder characteristics means what you have in the powder how much of CaO, how much of you know Si2, how much of alumina, how much of calcium fluoride, how much of sodium oxide all these will give you not only what is the melting point, melting point is important because the powder should melt and form the slag. So, that is important the viscosity is important of whatever mould whatever you know slag is forming in the mould, what is the viscosity what is the interfacial tension. If it is very viscous it cannot you know penetrate at the surface of the mould. So, this is very important.

So, powder characteristics are very important; this will determine the mould heat transfer why this will determine? Because the mould slag from here because of this oscillation is getting sucked inside here. So, this film, the film characteristic will determine what is the

heat transfer here this is very important to understand. It will give lubrication it will give heat transfer. So, what is the films characteristic, how much of you know heat transfer will again there is not a only there liquid slag; the some of the liquid slag will solidify also because you are cooling it. So, there will be initially a solid slag then there is a liquid slag, what is the relative thickness of this solid and liquid slag all these are important. They will give you the lubrication they will give you the heat transfer.

So, if the casting process speed superheat is important, powder characteristic is important, mould lubrication depends on this, then mould oscillation and setting I have told you, what is the frequency oscillation, what is the amplitude of oscillation all these are important. What type of steel you are casting oscillation depends on that, you know oscillation is not same for all types of steel. So, this is very important.

Then I have told you after primary cooling, primary cooling is then the mould. Heat transfer depends on the type of powder, but in secondary cooling; that means, below the mould when you are cooling with either what are or you know you may cool with air mist. So, what is the extent of secondary cooling what is the distribution, how intense is it how it comes down, at what ratio it should come down from the top to bottom, this is very important these are all part of casting process.

Now, another important is I have discussed a bit of it, sub entry nozzle configuration and submergence. I have mentioned that liquid steel is coming down from tundish to mould through sub entry nozzle a refracting nozzle. We call sub entry nozzle, what is the configuration? Configuration means how it is coming out, what is the port size, what is the shape, whether it is circular or is a elliptical what is that you know angle of the port whether it is the steel will come out horizontally or at an angle, at the top or the bottom what is the angle that is important.

Submergence how much the SEN will be submerged in mould all these are important these are part of the casting process. I mean all this will determine how much there will be oscillation, how much there will be you know what is that called turbulence in the mould these are all important, what is the heat transfer all these are important. So, casting process is important, I have told caster type and alignment is important, then I have told specific steel grade is important.

Why this is important? Solidification mould solidification sequence will depend on the grade solid may be first delta or it may be delta plus gamma or it may be gamma and then when gamma forms whether it forms during solidification stage or after solidification or at the very beginning itself gamma is forming these are very important. Because solid shell whether it is delta gamma or delta plus gamma all this will depend all will impart the thick you know strength and toughness of the solid shell.

Then sticking or depression tendency is very important, this grade of steel will determine whether during casting process the shell will try to stick to the mould or try to come away from the mould this I will discuss in details. So, we will come to know there will be two broad possibilities. Some of the grades are we call it sticking type; that means, the shell is having less strain or shell is so narrow so thin, that it cannot withstand the ferrostatic pressure it will try to come towards the mould. So, it is called a sticking type.

Certain steels the shell may be slightly thicker or shell may be of higher strength. So, you know the contraction may be more there. So, it will try to come away from the mould. So, whether it is coming towards the mould or away from the mould will determine whether it is sticking type or depression type. I have told you the depression is a typical defect. So, depression type of grades certain grades are depression grades, we have surface where there are some depressions and relations which are undesirable.

So, this steel grade will you know determine then high temperature strength and ductility as I have told this is determined by the grade only specific steel grade. Then what are the trace elements present this very important I have told you because how much of sulphur, phosphorous, boron, aluminum, nitrogen why these are important? Because this will give generate segregation all elements will generate segregation, but these elements I will come when I discuss in details you will come to know, why sulphur phosphorous boron these are more prone to segregation. They will get more segregation and they are I mean problem of defects generation and mould this stress elements.

So, a control of these elements in during secondary refining is very important more you have these elements more is the problem. They not only create you know segregation they depress the solidus temperature. Whatever you find from the phase diagram is an equilibrium solidus temperature, but in reality during casting you have to deal with actual solidus temperature, because micro segregation will be there the segregation will

depress the solidus temperature from the equilibrium to the actual value which is always lower.

As I have told always segregation will be there, always the all this solubles will try to be more in the liquid than in solid which can which will always happen and because of that the solubility because of this increased solubility in the remaining liquid, the portion which is solidifying at the later stage will have more of this elements and the last liquid which is solidifying will solidus temperature it is always coming down because of this. So, these are all issues which have to be taken care of we have to be careful, then only we should have a good cast product otherwise you know all these types of defects will come.

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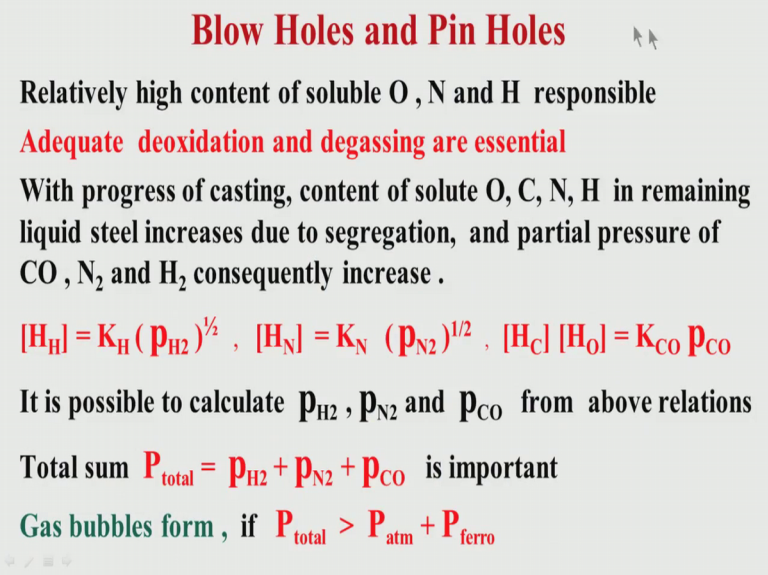

Now, I will just try to discuss why blow holes and pin holes are created. I have told you here that blow holes and pin holes they are basically coming from the gas content this is one type of defect. Now to what extent we can control them we will now discuss. Relatively high content of soluble oxygen nitrogen hydrogen I had mentioned these three elements have to be properly controlled in liquid steel before you cast. So, otherwise you will be having blow holes and pin holes.

So, what is important is adequate deoxidation and degassing. Oxygen you are controlling through deoxidation, and nitrogen hydrogen you can control through degassing this I

have discussed you know earlier when I discussed about how to control all these elements in steel in secondary refine.

So, adequate deoxidation degassing are essential now what why there is a problem during casting let us try to understand. With progress of casting, as I have mentioned due to segregation content of solute oxygen, carbon, nitrogen, hydrogen remaining liquid steel this is increasing due to segregation. So, initially whatever content of oxygen carbon nitrogen hydrogen you have started in the liquid steel, as you are going ahead with solidification; that means, with progress of solidification the liquid steel is getting more and more rich more and more segregated with oxygen carbon nitrogen hydrogen all these elements this is related to segregation.

So, what is the problem if this all increases? First the basic base level is important, but the base from the base level also we are going getting more and more of this during the course of solidification. First the base level has to be low, that is first thing then only whatever increase is there will be within a certain limits.

Now, we know I think we have discussed with this that hydrogen nitrogen oxygen these are coming out of liquid steel in solid steel, like whatever hydrogen is there in liquid steel during solidification it will come out as gas. So, it come out as what gas. So, this is the from the reaction you can know hydrogen which is solute in liquid steel, and is coming out of liquid steel in solid in the form of a gas.

So, from this relation this is the constant. So, from this is fixed for at a particular temperature. So, at a particular temperature we know what is the amount of suppose we know amount of hydrogen this is the henrian activity. We know that hydrogen nitrogen oxygen these are very present in a very low amount in liquid steel. So, we can take henrian activity as equal to the percentage of p p m of this elements or percentage of this elements in liquid steel.

So, henrian activity is equal to this constant into partial pressure of hydrogen to the power half; that means, if you know this how much of hydrogen is present, we can this value is known from the you know (Refer Time: 25:49) properties. So, we from this reaction we know at a particular temperature this is fixed. So, we know; what is the partial pressure of hydrogen for a particular value of hydrogen.

Similarly, for nitrogen we know what is the partial pressure of nitrogen, if the partial pressure of hydrogen and nitrogen are more, partial pressure of nitrogen hydrogen also will be more because this is an equilibrium with this, this is fixed this is more solubility is more we have more of partial pressure of hydrogen solubility of nitrogen is more, we have more of partial pressure of nitrogen. The solubility of carbon and oxygen is more multiplication of this, partial pressure of carbon monoxide will be more because this is fixed at a particular temperature.

So, what is happening? If you have more of hydrogen, nitrogen, carbon and oxygen in liquid steel, you have more of partial pressure of hydrogen more partial pressure of nitrogen more of partial pressure of carbon monoxide, which is coming out in the form of gas bubble in solid. So, more of this means more of the partial pressure of this.

So, what is going to happen? So, first thing is we can calculate from this values, what is the partial pressure of hydrogen, nitrogen, carbon, monoxide I think it is clear. Because these reactions I have discussed earlier at the time of degassing or decarburization I have discussed all these reactions. So, you know we know this values hydrogen, nitrogen, carbon, oxygen we know partial pressure of hydrogen nitrogen and carbon monoxide.

So, total of this total of these three is hydrogen nitrogen carbon monoxide is important. This total value if it is more than the atmospheric pressure and the ferrostatic pressure then gas bubbles will form. You try to understand what is happening; because of hydrogen nitrogen and carbon and oxygen in liquid steel, when you are during solidification they are trying to come out in the form of gas. So, there is a partial pressure of hydrogen nitrogen and carbon monoxide depending on how much of hydrogen nitrogen carbon and oxygen is there in liquid steel.

Less is this value or hydrogen nitrogen carbon oxygen less will be the partial pressures and if the partial pressures are low, P total is low total pressure from this partial pressures are low if the pressure is low, then it is less than atmospheric pressure and ferrostatic pressure. I have told you there is liquid steel, there is liquid steel at the time of solidification when the solidification is complete then only there is no liquid steel. So, there is a ferrostatic pressure.

As you are coming down the liquid steel as I have mentioned, ferrostatic pressure is increasing is it clear. When the solidification is starting ferrostatic pressure is almost nil

because you know solidification is starting at the top of the caster, top of the mould as you are coming down. That means, solidification is getting more and more compete at the almost at the end of solidification, you know this pressure ferrostatic pressure is high. So, what I have told here is this summation of the three partial pressures should be less than atmospheric pressure and the ferrostatic pressure, if it is so there will be no gas bubble formation. They cannot form they cannot you know come out in the form of gas. So, there will be no blow holes and pin holes are it clear.

So, what is the secret of restricting blow holes and pin holes? You have less amount of dissolved oxygen, less amount of dissolved carbon, less amount of nitrogen less amount of hydrogen carbon of course, carbon and oxygen are inter related if you have more amount of dissolved carbon your dissolved oxygen will come down. So, carbon is of course,, something related to the what is that called your chemistry of steel forget about carbon, but you should have less amount dissolved oxygen less amount of dissolved nitrogen less amount of dissolved hydrogen.

So, if you have less amount of this partial pressures of hydrogen, nitrogen and CO will be less, total pressure will be less. So, it will be less than this. So, there will be no blow holes and pin holes. So, please remember the secret of having no blow holes and pin holes in liquid in you know cast product in your continuous casting from you know liquid steel to the slab bloom or billet whatever it is or even during ingot casting this is true. This is in principle true for everything, but only thing is ferrostatic pressure here it is increasing at the end towards the end of the continuous casting here towards the end of continuous casting solidification.

So, we have to remember this relation, total pressure of these three partial pressures hydrogen, nitrogen, CO has to be less than atmospheric pressure and ferrostatic pressure. In that case there will be no blow holes and pin holes with we will have more of hydrogen nitrogen oxygen means more of partial pressures. So, the total pressure will be more and if it exceeds total pressure exceeds the summation of atmospheric pressure and ferrostatic pressure you have blow holes and pin holes which is undesirable.

So, as I have mentioned at the first requirement of a good cast product is absence of blow hole and pin hole, and for that we have to do must have low amount of this contents, we must do good deoxidation. We must do good degassing to take care of hydrogen and

nitrogen this is the first requirement then only you have absence of blow holes and pin holes. I have tried to explain; what is the principle why does it form.

I think we will next discus maybe in subsequent lectures, how the other defects are generated.

Thank you very much.