Steel Quality Role of Secondary Refining and Continuous Casting

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Module - 04
Lecture -17

Nature and Distribution of Entrapments in Casting

Suppose we have done the casting, then if you look at the you know casting interior you will find it is not uniform, the quality is not uniform, inclusions are not uniformly present because of the nature of the solidification, because how continuous casting takes place the entrapments, the distribution in inside the you know slab or bloom or billet inside the cast product is not uniform. Like even in any ingot it is not uniform. In certain portion of the ingot you have more contamination, more inclusions. In the continuous cast product also whether it is slab or bloom or billet certain areas have more entrapments, certain areas have relatively less.

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Now, I will try to come to that one by one. Start and end of casting: why there will be mould inclusion, because at those points of time there is a possibility of re-oxidation, because you know you have not you are just putting the Shroud Argon; Shrouding has just started so some amount of re-oxidation is possible. So, these are a distinct possibility at the start and end of casting.

Then another problem is a Tundish slag. As I have told you, you do not allow the Tundish to get emptied at the end of the casting; because the Tundish has liquid steel on top of that there is slag. So, if you totally empty the Tundish at the end of the casting then what happens, the Tundish slag also try to get inside the mould which is not desirable. So, some amount of, some this all will some amount of liquid steel should always be kept inside the Tundish.

So, this is facilitated when we are using dam and weir; that means, too much of we are not wasting too much of liquid steel in a Tundish, because dam and weir we try to contain try to reduce the amount of liquid steel which can remain in Tundish. So, the Tundish slag should not be allowed to come under any condition within the mould.

Then, in steady state casting: steady state casting means, we have started the casting, the speed slowly you have increase the speed and the speed is remaining constant. So, that stage is called steady state casting. So, during that stage there is a possibility though not much high, possibility is relatively less in steady state casting, but there is a possibility of mould slag entrainment in liquid steel. As I have told you the interfacial tension, the viscosity all these play a role. Because at the interface even if there is small amount of turbulence there is a possibility of liquid slag getting entrained in liquid steel?

So, the characteristics of the mould powder are very important from which mould slag is getting generated. Interfacial tension should be slightly higher; viscosity should be whatever viscosity optimum viscosity should be there so that this does not get entrained. Then at the time of ladle changeover; I have told you in continuous casting one ladle goes another ladle comes, but the casting continues because there is a buffer called Tundish. But at the time of ladle changeover there is a possibility of ladle slag which is coming inside the Tundish. So, as I have told you, you must not allow ladle slag to come. So, the detection of ladle slag at the end of ladle at the stage of enting the ladle changeover ladle is very important or we have to keep some liquids when there is no detection as I have told you all here we have to keep some amount of liquid steel in the ladle so that does slag does not come.

Then, another important thing is- sudden changes meniscus level or speed. As I have told you there is a possibility of more slag or even powder. So, the possibilities of entrapments are not uniform in the casting. So, when you are from the casting, when you are finally rolling the cast product to get the desirable you know final product whether it is hot rolled or cold roll if you look into their you know inside you will find that there will be more defects in rolled products corresponding to start or end of casting. Just after the ladle changeover there will be slightly more of defects. Whenever there was a sudden fluctuation during continuous casting there will be more defects exogenous entrapment.

So, this is important to understand and to keep in mind that whatever product you are getting from continuous cast: slab or bloom or billet it is not uniformly having good quality, certain areas of it, certain portions of it are may be having some problems. If you know what are those areas then we can be do something. Like you know start or end of the casting what happens the product which is the slab or bloom or billet whichever is getting cast at the that stage you may keep it separate because it is marked. We do not allow them to go for a good quality product. Because as I have told you like in our liquid steel how much of total oxygen is there that gives them indication how the cast product will be whether it is good or bad, how the rolled product it will be it is good or bad.

Similarly, we know that the cast slab or bloom or billet which has been cast at the start or end of casting or whenever there was a ladle changeover that portion of the casting, there is a possibility it will be relatively of inferior quality. So, we may separate out those portions to get desirable quality of final product.

So this is important, because if we know; what are the areas of the casting or which portion of the casting there is a possibility of you know less cleanliness, more inclusions, more entrapments. If you know it is better we separate out those portions it is possible nowadays people do that you know; start of casting, end of casting, ladle changeover people try to separate reprocess it keep it separately because there is a possibility and it has been shown also that yes those areas are relatively inferior in quality.

So, we have to be careful when we finally, process the you know cast products which portion of the casting we are processing if we know that certain areas are relatively more prone to problem more prone to inclusions entrapments more probable to have less cleanliness oxide cleanliness more of entrapment. So, we should process them separately that is what is important.

Now, let me just go through what are the complex oxides large entrapment I have told the large entrapments are not good.

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In the cast product because they might create surface defects they might create additional problems. So, what are the complex oxides as large entrapments aluminum oxide this is a this can be what this can be oxidation product this can be a re-oxidation product it can be nozzle clogging product it can be a refractory erosion product with minus silicon and manganese oxide these have been. In fact, when I will come to it later on we can measure what are the or we can rather evaluate what are the constituents present in some defect areas.

Suppose we have got a defect in a particular area of the product hot rolled or cold rolled product we can cut that portion we can see it on the microscope on the scanning electron microscope to know what are the constituents present. So, from that study only we have found out that what are the complex oxide which can present as large entrapments. So, one is the aluminum oxide this can be present due to re-oxidation due to nozzle clogging due to refractory erosion then there can be a combination of calcium oxide silicon oxide aluminum oxide what is that where from does it come it is basically slag it can be either ladle slag either Tundish slag or mould slag.

Now, there is some relative difference ladle slag you have more amount of calcium oxide all of you know may be around more than fifty percent will be calcium oxide in the ladle slag Tundish slag it is slightly more reaching silicon oxide because you know you are using nice as I have told you. So, some amount of silicon oxide will come in the slag more slag you know some amount of sodium oxide is present some amount of calcium fluoride is present. So, mould slag with the presence of sodium oxide calcium fluoride these indicates that mould slag might have get entrained.

So, whenever you have calcium oxide silicon oxide aluminum oxide constituents in the defects know that it is basically the slag. So, we have to be done careful we have to do some you know back calculation we have to find out why it has contamination is taking place what was the problem another you know entrapment exogenous entrapment may be zirconium oxide which is coming from the ladles nozzle sand I have told you we have to be careful about the nozzle sand it should not be allow to drop inside the Tundish when you are opening the time of opening we have to be careful. So, basically it is reaching zirconium oxide.

So, these are the complex oxides exogenous entrapments which can get entrapped in liquid steel and finally, you will you may find them in certain portion of the continuous cast product during rolling you will go inside the final product and will create problems quality issues there may be surface defects all these we will discuss in details later on, but what I am trying to tell here; I have mentioned again I have mentioned earlier also again I am mentioning thus entrapments which have larger in size more than hundred micron hundred micron or more that result in surface lamination in role products.

So, we have to be very very careful about these entrapments particularly large entrapments which might come during from re-oxidation from nozzle clogging refractory erosion from the slag whether it is ladle slag Tundish slag or mould slag or nozzle sand these are some of the you know exogenous entrapments some of the sources of exogenous entrapments which create problem quality issues and which must be taken care of which must be very careful to prevent these in at the time of at certainly defining at the time of continuous casting everywhere we have to be careful. So, that there is less possibility of entrapment exogenous entrapment like re-oxidation product nozzle clogging product refractory erosion product slag from ladle Tundish and mould they should not get entrapped or entrained in liquid steel.

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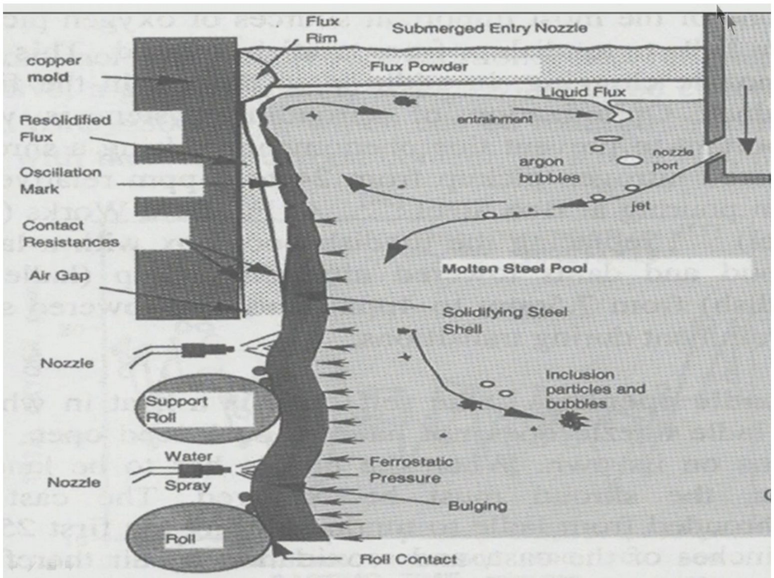

I talked about the mould what are the precautions we have to take in the mould. So, that the exogenous entrapments do not take place. So, I talked about you know initially from the sub entry nozzle this is away this is the port through which liquid steel is coming out and through this port Argon also is coming you know being blown in it is coming out in the liquid steel pulled here this is within the mould this is the mould copper mould which is getting cooled.

So, at the top of the liquid steel there is a liquid flux we called it mould slag and because of the oscillation of the mould which is necessary for the casting continuous casting save continuous casting smooth continuous casting it is necessary this part of the liquid slag is getting inside at the interface between the mould and the solid shell this is also an important requirement this helps the mould shell not getting stuck. So, sticking does not take place if there is a liquid inside.

So, this is the solid powder solid solidified slag and this is the liquid slag. So, this is the flux rim this is the flux powder and just at the top of the liquid steel has a liquid flux. So, as I had mention the turbulence at the interface between the liquid slag and the liquid steel is very important if there is too much of turbulence I mean there is a possibility of entrainment of the liquid flux or liquid you know mould slag getting entrained in the liquid steel.

So, we have to be careful about that this shows how you know this Argon bubbles with this liquid steel how it is mixing getting intermixed and how the inclusion particles and bubbles they are coming like this sometimes going up then finally, coming down and finally, will go up like this is this is the half of the mould you know this is the SEN this is one end of the mould the other end will be somewhere there.

So, what is the half of the mould we are showing in this particular picture? So, the turbulence between the mould is very important we have to be careful thus there is not too much of turbulence too much of turbulence will cause possibility of mould slag entrainment if there is too much of turbulence again there is the possibility of flux or powder entrapment if too much of fluctuation in the surface may here meniscus this is called the meniscus. So, this is very important.

Now this I had mentioned that the design of the port is very important because whether liquid steel should come down like this or should the flow should be in horizontal the port angle should look up; that means, the flow should be slightly towards above. So, this is also very important. So, modeling can decide what should be the turbulence what extent turbulence can be tolerated these are the issues which can be sorted out through modeling.

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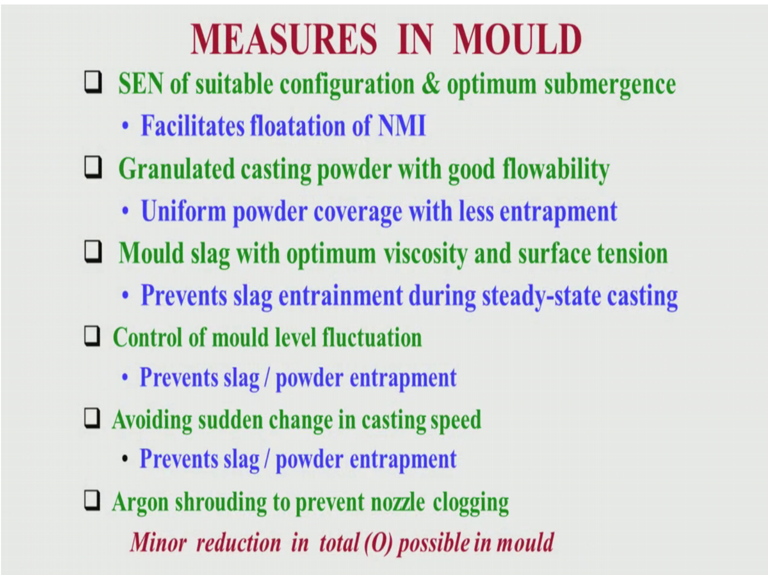

Then I talked about what are the important measures in mould like SEN the sub entry nozzle of suitable configuration and optimum submergence these basically decide what is the level of turbulence that is very important this facilitates floatation of n m I non medaling inclusions whether they are getting generated or if there are some exogenous entrapments they should float up the turbulence should be such that they should float up and get absorbed by the liquid slag that is very important. So, this sub entry nozzle configuration port angle and how it is what angle it is there what is the size all this will decide what is the level of optimum submergence this will decide whether the turbulence is optimum or not.

Then I have mentioned that the instead of normal powder we should use granulated casting powder which has good flow ability you know normal powder there is a problem of getting flow abilities of problem, but you have a granulated casting powder it has good flowability. So, this helps in uniform powder coverage with less entrapment this is very important powder coverage at the top should be you know this powder coverage at the top should be uniform require not only from the heat transform point of view which is also required from the point of view of you; you know uniformity of the casting as a casting should be stable stability of casting also it gives this flux by uniform flux powder will give you know uniform heat transformer and you may form uniformity in the casting operation.

So, I have talked about the granulated casting powder talked about the mould slag who should have optimum viscosity and surface tension this is required because you know if the viscosity and surface tension at the interface is not uniform or optimum rather there is a possibility of slag entrapment during steady state casting normal casting there is a possibility of slag entrapment if viscosity and surface tension not very optimum.

So, that I have mentioned that mould level fluctuation is very important because first there is you know movement of the mould in a vertical and downward direction which is called mould oscillation. So, oscillation should be such and the flow of the liquid steel from the SEN should be such that there is not too much of mould level fluctuation. So, this can be measured mould level fluctuation if there is too much of fluctuation then there is a feedback and this can control the level of you know movement level of requesting movement. So, there is a possibility of controlling the mould level fluctuation.

So, it has to be within certain limits solid layer within the limit of plus minus 2 millimeter mould level fluctuation. So, this helps in preventing slag or powder entrapment there is a too much of fluctuation there is a possibility of slag or powder entrapment then I had mentioned that sudden change in casting speed is not desirable what happens if there is a sudden change in casting speed; that means, too much of liquid will come out in this mould which will be again generate lot of fluctuation. So, that is not desirable. So, therefore, what is important is to control the sudden change in casting speed once you reach a you know the speed desirable speed of say point eight or one meter per minute the desirable thing is to continue with that that is called steady state casting there should not be a fluctuation in casting that is that should be avoided under all circumstances.

Then of course, this is very important Argon Shrouding to prevent nozzle clogging the port should not get clogged there is a possibility of clogging here because you know that is small amount of dissolved aluminum in liquid steel. So, if there is a air in gas there is a possibility of formation of alumina if there is titanium in liquid steel there is a possibility of formation of titanium oxide these are solid at a temperature of liquid steel. So, there is a possibility of clogging.

So, Argon you know flow is a must this will prevent you know formation of alumina titania; this type of oxides which are solid. So, Argon flow Argon cover is very important. So, with if you undertake all these precautions if you do casting with all these precautions in the mould. Then there is a possibility that not only you know entrainment of liquids or rather mould slag will be prevented. There is a possibility of some amount of re-oxidation is possible some amount of you know total oxygen which will which will allow the inclusions to float to the surface and get absorbed by the slag.

So, there is a possibility of minor reduction in total oxygen also; that means, there is a possibility of cleanly level cleanliness level increase in mould as well then I have mentioned that the exogenous entrapments; how the; what are the complex large entrapments aluminum oxide along with minor silicon or manganese oxide there can be from the re-oxidation product from the nozzle clogging product from the refractory erosion product.

Now, what happens when there is a you know nozzle clogging if there is a nozzle clogging here when there is a flow of liquid steel; that means, the clog some amount of clogged material will be dislodged from the port and will get inside the liquid still in the mould. So, that is the sources of exogenous entrapment again. So, clogging not only creates a problem for the normal casting, but from the cleanness point of view also there is a problem. So, we have to be careful about that

So, aluminum oxide are along with some minor silicon or manganese oxide this is a typical entrapments which might come from re-oxidation might come from nozzle clogging might come from refractory erosion products. Now I have talked how the slag entrapment or entrainment if the ladle slag comes that is also not desirable I have mentioned there has to be a proper control that ladle slag should not be allowed to get inside the Tundish then the Tundish slag also should not be allowed to come towards the end of the casting within the mould. Then the mould slag also should not be allowed should not be allowed to get entrained by controlling the mould level fluctuation by having suitable mould flux characteristics of suitable viscosity and interfacial tension. So, that mould slag does not get entrained.

Now, there may be a possibility of zirconium oxide which is ladle sand I have mentioned ladle nozzle sand which has to be prevented from getting inside the Tundish when we are opening the ladle exit. So, these entrapments which are large more than 100 micron they result in surface lamination in rolled products.

Thank you very much.