Modeling of Tundish Steelmaking Process in Continuous Casting

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Lecture – 05
Tundish Metullergy

Welcome to the lecture on Tundish Metallurgy. So, we have already discussed about the role of tundish in continuous casting and we know that the tundish is acting as a metallurgical reactor. And, you know because this steel is coming from the ladle and then going from the tundish to the mold. So, some of the you know treatments are even done before the metal enters into the tundish and of them includes like there may be treatments to the melts. So, that certain kind of inclusions are you know or inclusions are basically filtered out or for controlling the composition of the steel also.

However, you know we must know that what are those aspects also which needs to be studied regarding the treatment which is done in the tundish also which has basically the bearing on the metallurgical behaviour of the product and what are those capabilities which affect that way. So, that you know basically will be covered under the aspect of this topic that is a tundish metallurgy. And, especially we will talk about you know those phenomenas which are take place inside like we can have certain treatments related to the modification or treatment so, that the inclusion removal is more or you know other you know aspects like the vortex formation or so.

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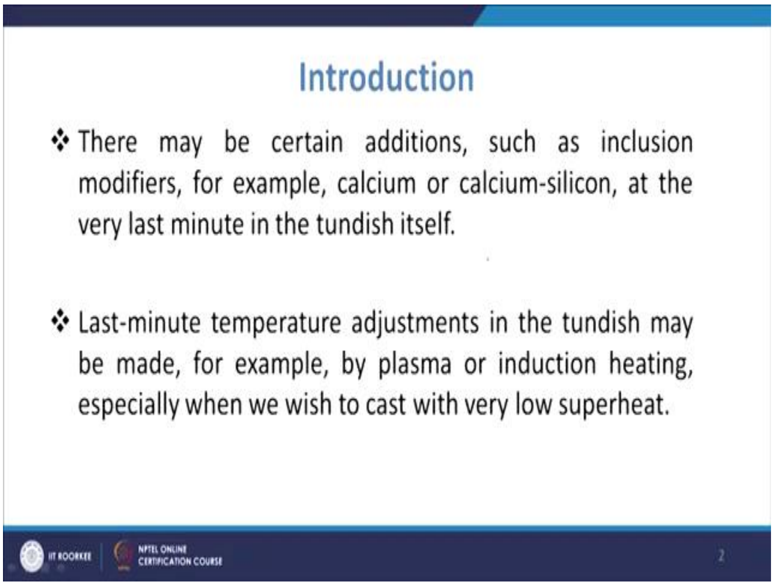

So, we will have the light on these aspects. So, what we see that normally as a metallurgical reactor, we feel that in the tundish you know there should be I mean the tundish should be working in such a manner that there should be you know even you know heat throughout the domain in the tundish. Then there should be proper you know flow, configuration inside the tundish.

So, that there is proper use of the space which is there or proper use of the volume of the tundish, then you know you have to do something also your flow control has to be such that there has to be you know minimum of the inclusions which should further go down the tundish from I mean from the tundish outlet towards the mold. And, also we need to see that how you have to see that the there is no vortex formation when there is decrease in the level of the tundish, then there should not vortexing phenomena and all that.

So, one of that process is that you may have certain additions like inclusion modifiers like calcium or calcium silicon at the very last minute in the tundish itself. So, what happens that although we do certain treatment so, that inclusions are you know we try to trap them, we try to see that minimum of the inclusions come into the tundish.

But, still if the inclusions are coming inside the tundish, then we need to you know have certain treatment and maybe sometimes we add like inclusion modifiers like calcium or calcium silicon; you know at the very last minute in the tundish. So, you know so this so, that basically will help in the control of the inclusions or you know that it will help in the treatment of the inclusions so, that inclusions either float or inclusions are modified.

There are modifications to those shape and size of those inclusions or their properties. So, that ultimatum is that these inclusion should be you know minimum in the melt. Other aspect is also about the temperature adjustment in the tundish you know because from the tundish, it is directly going to the mold. And, if the temperature becomes very less so, in those cases that may affect the quality of the cast because it has to go into the either a mold and then further it has to be you know it has to get solidified.

So, many a times what we do is we do the heating. We have the heating arrangement also in the tundish. So, that you see that the proper you know temperature is maintained throughout the tundish volume. You know we have already talked that there may be you know change in the flow pattern because of these temperature differences, there may be formation of the convection loops, there may be you know thermal current which may be there inside that and this so, that may alter the you know flow configuration inside the tundish.

And many a times if the temperature is becoming you know very very small in certain areas which is most likely a dead region inside the tundish. In those cases, you need to have the you know temperature adjustment mechanism, you need to heat the tundish also in those you know the liquid in the tundish in those areas. So, that the temperature is well above you know ice melting point so, that you know there is no undesirable thing happen like solidification inside the tundish itself.

So, we do the plasma or induction heating especially when we wish to cast with very low superheat. So, especially when we are trying to cast with very low superheat and if there is a temperature drop undesirable temperature drop in certain region, they that may be producing some undesirable you know outcomes. So, in those cases, we have to go for a certain kind of heating mechanism like plasma or induction heating. So, that is also you know done.

So, ultimate aim our ultimate aim to in the tundish will be to have the clean steel and you know that is because you know this requirement for the steel has been increasing over the years. So, it is because you know that they are used for critical applications and the presence of these inclusions make the properties of the steel inferior you know. So, what has been the practice that we try to improvise those technologies we are working on the better technologies so that we can get rid of the inclusions. And in fact, our effort is to go for the inclusions because there are mechanisms to filter out the larger size inclusions, but then we have to see that these size inclusions critical size inclusion pie you know sizes become less and less which must be removed.

So, it is because all these properties like strength, ductility, durability, corrosion resistance. So, they we are working on it to have the its you know improved properties over the years.

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And also that is possible normally if you are making the steel cleaner you know of the non metallic inclusions which are most likely deteriorating these properties for which we normally use steel. Like if the inclusions are there, the strength may go down ductility may go down and durability as well as corrosion resistance all these things are impaired; all these properties are impaired if you have the presence of these non-metallic inclusions.

If you talk about the non metallic inclusions in steel normally they are of two type: one is the indigenous oxide inclusions. So, they normally are formed by the de oxidation of the steel melt and then you have exogenous you know inclusions. So, there are basically these are the two types of these inclusions.

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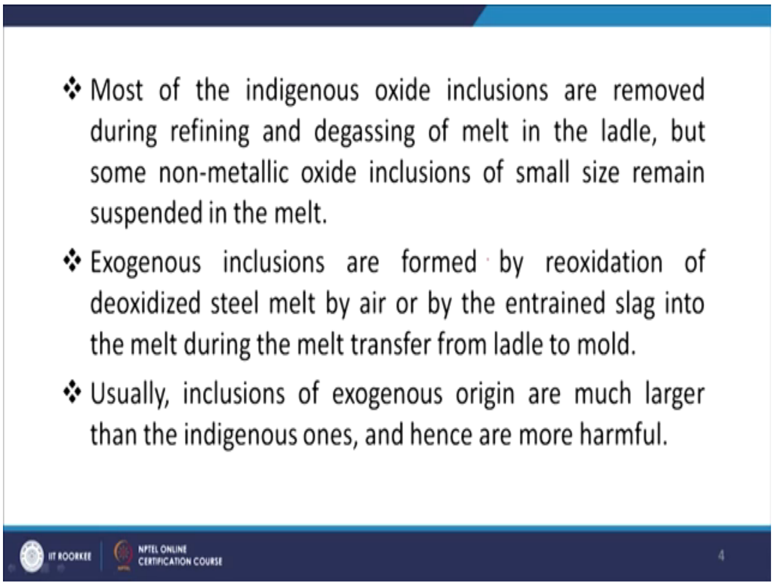

So, if you talk about these indigenous oxide inclusions so, they are basically removed during the refining and degassing of melt in the ladle itself as we discussed that we do certain treatment in the ladle itself. We try to you know remove these indigenous oxide inclusions you know by during that refining as well as the degassing of the melt in the ladle. But some of these non-metallic oxide inclusions of a small size still remain suspended in the melt.

So, they will be coming to the tundish and then if you have the then you have the second variety of inclusions that is your exogenous inclusions. So, they are formed by the reoxidation of deoxidized steel melt by air or by the entrained slag into the melt during the melt transfer from the ladle to the mold. So, that basically is because of the reoxidation of these deoxidized steel melt which we have done. So, that there is further you know chances of reoxidation and also because of these slag which is you know these that slag into the melt which you know may pass down.

So, what happens that these inclusions which are of the exogenous origin so which is formed because of the reoxidations. So, they are normally much you know larger than the indigenous ones and they are very very harmful. So, larger inclusions will be harmful than the you know smaller ones.

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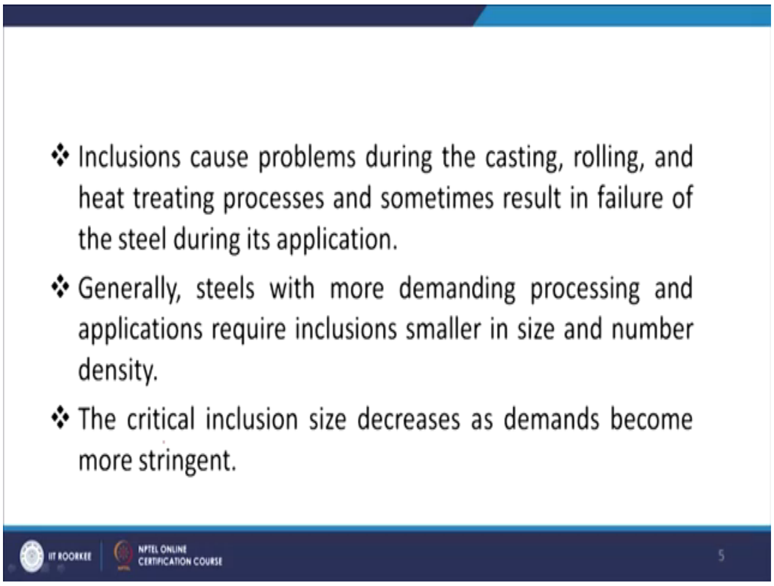

So, you know how they are harmful because these inclusions you know what they do is they will be causing the problems during the casting rolling and heat treating processes. So, you know as you know that if there are inclusions, they will be as the defect in the cast product. If they are in the rolling so, rolling also they make difficult and also during the heat treatment process.

So, in all these processes because when there are inclusions their properties not as same as that of the parent metal; it has not the ductility same normally, they are brittle. So, what happens that the result in the failure of the steel during its application. So, that is why you know these in inclusions are you know said to be removed mostly. We try to remove these inclusions as to the extent as we can.

So, you know steels with more demanding processing and applications require inclusions which are smaller in size and number density. So, it means that if you have to have steel of better quality. So, there are the requirement is that the inclusion size should be smaller and similarly the number density also should be is less number of inclusions should be there as well as this smaller you know inclusions you try to have that.

So, that is why you are more demand you demanding processing and applications are required nowadays and critical inclusion size decreases as demands become more and more stringent. So, you say that the inclusion size should be you know not more than this size whenever, we talk about those you know very demanding steels or wherever you have to use the steel for the critical applications or so. So, the end user will specify that the critical inclusion size should be this one. It means you should not have any inclusion which is of larger size than a particular size that is your critical size of the you know inclusions. So, what happens that you know these larger inclusions are there?

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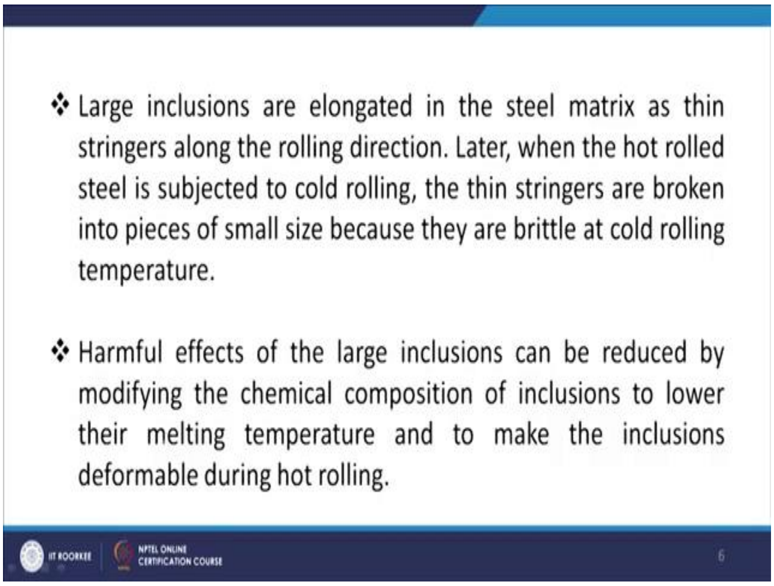

So, they will be elongated the in the steel matrix as thin stringers along the rolling direction. So, what happens that when you have larger inclusions and when you roll these slabs or boule billet us or ingots itself when you are you know further going for the rolling operation so, you know they are likely to be elongated you know and they will be like is a thin stringers in the rolling direction.

So, if you have the rolling direction like rolls are moving. So, like this upper roll like this, lower roll is moving in that way. So, it will be taking the you know strip in forward direction and your you know larger inclusions. So, they will be elongated in that direction. So, they will be if this size, they will be flattened and it will be in that you know in the rolling direction they will be elongated.

Now, further when the hot rolled, these steels are further subjected to the cold rolling then what happens that you know as the temperature comes down so, they become brittle. And, then when you are doing the cold rolling so, they will be breaking into the pieces of small size because they will be brittle to the these cold rolling temperature and that will be affecting the homogeneity of the you know component, they will be affecting the properties of the material and then there may fail also you know at those points.

So, what we do is you know harmful effect of these large inclusions which we get they can be reduced by modifying the chemical composition of the inclusions to lower their melting temperature and to make the inclusions deformable during hot rolling. So, as you see that if you have the larger inclusions so, the one way is that you can use these chemical modify the chemical composition of the inclusion.

So, that you can lower their melting temperature and then you know the inclusions can be made deformable during the hot rolling. So, one of the way you can have their effect you know less and less harmful will be by making these treatments.

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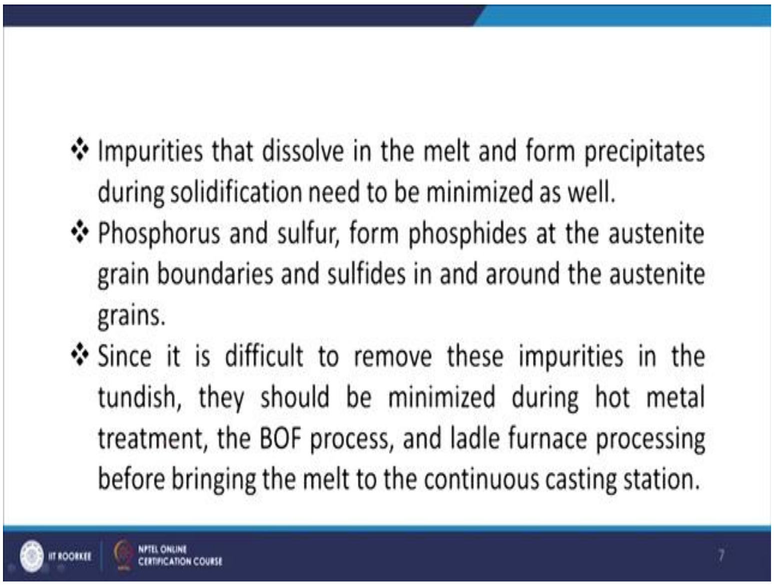

Then impurities which are dissolving in the melt and form precipitates during solidification so, you have also impurities which may be dissolving in which would like to dissolve in the melt and you would like to form precipitates during the solidification. So, you also need to minimize them as well. So, that also needs to be done. So, that your steel becomes cleaner and cleaner.

If you look at those impurities, typically you have phosphorus and sulfur. So, these elements will form phosphides or sulfides. So, these phosphates, they will be at the austenite grain boundaries and sulfides will be in and around the austenite grains. So, normally you know they are making these formability of the steel you know they challenge that property of the steel.

So, as you know, it is difficult to remove these impurities in the tundish because so, if they have to be minimized this will be minimized during the hot metal treatment, the BOF process and the ladle furnace processing before bringing the melt to the continuous casting station. So, you know once they are coming to the you know tundish, it is very difficult you know further to remove them because they have to be removed through through the treatment through certain reactions chemical reactions or so.

So, your effort should be you know there so, that you know during the hot metal treatment like the in the BOF process or the in the ladle furnace processing. Before you are bringing to the tundish itself, you try to remove you know try to have minimum of these phosphorus and sulfur and their and the formation of the phosphides or sulfides at the grain boundaries.

So, this you know needs to be ensured. So, that you know the chances of having those compounds formed at the grain boundaries or in and around these austenitic grain boundaries is minimum.

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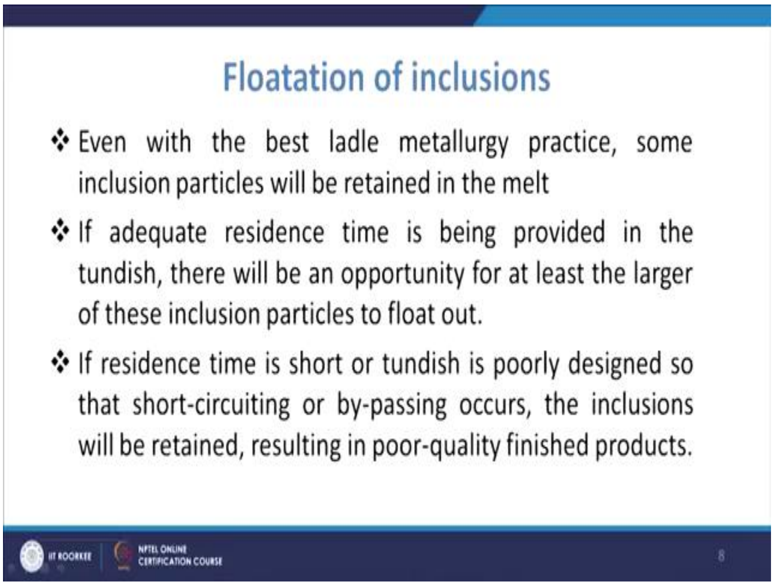

So, you know what we do is normally we go for the flotation of inclusions. So, one of the way is that you try to have the flow structure in the tundish in such a way that the inclusions have the tendency to float up. So, even with the best ladle metallurgy practice, some inclusions particles will be retained in the melt. So, as we discussed that we try to you know do the treatment in the ladle. So, that most of the inclusions we are trying to you know remove from there itself. But still as we had seen you know, the some of the inclusions they are likely to still come in the tundish and you know we try to we have now tried we have to try to remove the inclusions.

So, there cannot be any such treatment you know as we can do earlier to the ladle or in the lateral itself. But then by altering that flow pattern you know we can think of doing something so that these inclusions can be removed. And, one of the way is that you know by managing the residence time of these particles or the flow you know of the melt in the tundish.

So, if the adequate residence time is being provided in the tundish, there will be opportunity for at least the larger of these inclusion particles to float out. So, as we had talked about these role of these tundishes in the casting. So, there also we had talked that you know these steels which are going you know steel which is coming inside the tundish. Now these fluid particles as spend certain time inside the tundish.

So, it has some time before it comes out of the tundish outlet. Now this time that is your residence time. So, if it is very very small, these inclusions particles which are coming inside the tundish,, so, it will have a smaller and smaller chances you know to come out of it.

So, you know the way is that you give adequate residence time. So, you should have the flow structure in such a manner that once the you know liquid steel comes there so, you should have the flow in such a manner that you have the time sufficient time for these inclusions especially the larger inclusions to float out because the larger inclusions inclusions are having a smaller density as compared to the melt.

So, once you are they are settled and they have some time, then in that time basically they will be subjected to the bouncy forces because of the you know smaller density and then slowly they will be floating up. So, that is known as the floatation of the inclusions. So, that is a natural phenomena which has to occur because of the density difference and normally you know density difference will be about 0.5 to 0.6 times or maybe when go up to 0.67 times also.

So, you know they will have the chance to float up, but for that as we talked that the residence time has to be adequate and if that residence time is less we can do something by which the residence time can be increased in the tundish. So, those are the means why you know there are many means like you may use certain flow modifiers or and mostly by that or by you can have a tundish design where inlet and outlet us are positioned in such a manner that your residence time you know becomes maximum for a particular configuration or for a particular you know geometry of the tundish or with the use of flow modifiers.

If the resistance time is short or that tundish is poorly designed so, that short circuiting or bypassing occurs their inclusions will be retained resulting in poor quality finished product. So, what happens that if your tundish is such that the inclusions you know residance time is very very small? In that case the inclusion which is coming inside the tundish, most likely they will try to go directly towards the outlet and they will be going towards from the tundish outlet to the mold.

And, once they have entered into the mold, certainly there will be more you know likely that these inclusions become part of your product and then when they are coming going inside the solidified regions. So, they are trapped and then you know that becomes a part of your product. So, they are likely to be you know further rejected. So, your you have to see that you avoid these short circuiting or bypassing.

So, and mostly it you know occurs because of very poor sometimes, poor design of the tundish or you know you have not used the proper you know properly these flow modifiers in the tundish. So, all these concerns need to be addressed before you know and you must check that what is the average residence time. So, that you can be sure that if the residence time is larger, then the if that the there is inclusion you know they are likely to be you know going at the top of the you know on the tundish you know surface so, and there they will be trapped. So, that is how these inclusions are removed

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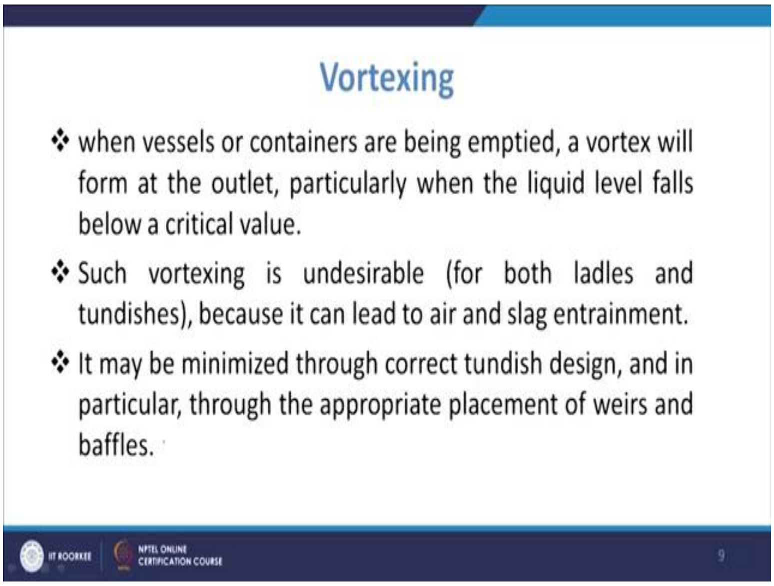

Then comes another aspect which needs to be understood is in in the case of tundish is the vortexing. So, this phenomena is of concern when your vessels or containers are being emptied as you know that, the ladle will be bringing the liquid steel from the shop and then they will be emptying that into the you know tundish. And, the tundish will be delivering the melt to the mold.

Now one ladle when it is emptied then another ladle comes and if there is if you need to you know siphon out all the liquid metal in the tundish so, that your next you know cast grade is of a very dissimilar type. In that case, you need to lower down and then further you are you know pouring in the another grid of steel into the tundish.

Now, while emptying when the level will come down to a certain height, then there may be a vortex formation at the outlet particularly when the liquid level will fall below a critical value. So, what happens that when the liquid level will come down so, that can be understood like you have the this is the tundish. And, if suppose you have the outlet here.

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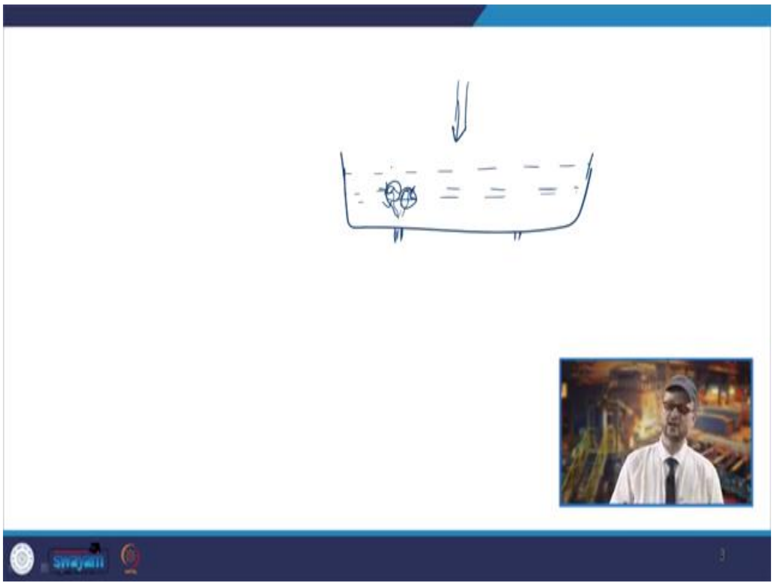

Now, what happens that when this is your inlet and liquid metal will come out. Now, what happens that when we use the you may use the flee modifiers or so. Now, these this is the level and it will be coming down and once you come to certain level down, then you may have the formation of the these vortexes and this vortex formation is nothing, but because it will be happening when the level will be falling down to a certain you know you know level.

So, that is critical level and these vortexing is nothing, but what it does is it will try to entrap the you know air and that air bubbles will be appearing and then that will be going inside that may try to oxidize the steel. So, that is harmful. So, we do not want the level to go down below a certain limit that is vortexing.

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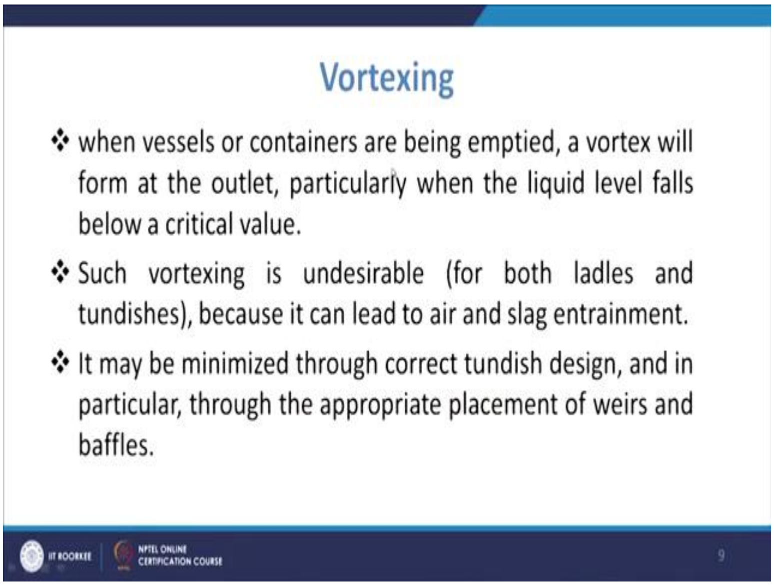

So, particularly when the liquid level will be falling below, the critical value and such vortexing is basically undesirable for both ladle as well as the tundishes both. In both the cases if the vortexing occurs, it may lead to the air as well as the slag interim entrapment because at the top you have the slag layer.

And, if there is vortexing occurring in that case, the air or the slag may be entrapped and it may go inside and once it goes inside, then that will be man that may be likely to have the there is likely to have the slag inclusions or there may be you know oxidation and there may be formation of inclusions there maybe oxidation of the melt also.

So, basically you will have to see that these vortexings is avoided. So, this vortexing we can you know minimize through the correct tundish design and in particular to the appropriate placement of weirs and baffles. So, these vortexing can be minimized by if we have proper tundish design as well as tundish furniture, we use that is your weirs or the baffles or dams.

So, you must have the appropriate placement of these weirs and baffles. So, that it basically helps in ensuring that there is no vortexing in the tundish. So, that is another part which you know has to be taken care of while we try to see you know that what should be you know those mechanism by which you can you know avoid these vortexing.

Apart from that, we also talked about other mechanisms are there like you have the heating mechanism. You can use the plasma torch who you do we do the other heating mechanism. So, that the temperature are you know kept homogeneous inside the tundish you know because and in many cases as we have studied in most of the cases its challenging when we are using the steel of which is to be used with very low superheat. So, there are some ways by which all these plasma heating or with other mechanism, you can have you know those you have plasma torch so, that is being used nor normally for maintaining that temperature.

So, all these you know aspects are needs to be studied and we will be talking about them in the lectures to come.

Thank you very much.