Modeling of Tundish Steelmaking Process in Continuous Casting

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Lecture - 02
Role of Tundish in Continuous Casting

Welcome to the lecture on Role of Tundish in Continuous Casting. So, in the last lecture we talked about the introduction about the continuous casting process and we discussed about the various components of the continuous casting process; which starts from the ladle, then you come to tundish, then further you are going to the mold, so you have strand portion. Now we are going to have the introduction about the role of the tundish in continuous casting process.

So, as you know that tundish is between the ladle and the mold. So, it is an intermediate vessel to transfer the finished steel melt from a ladle to the mold in a continuous casting machine.

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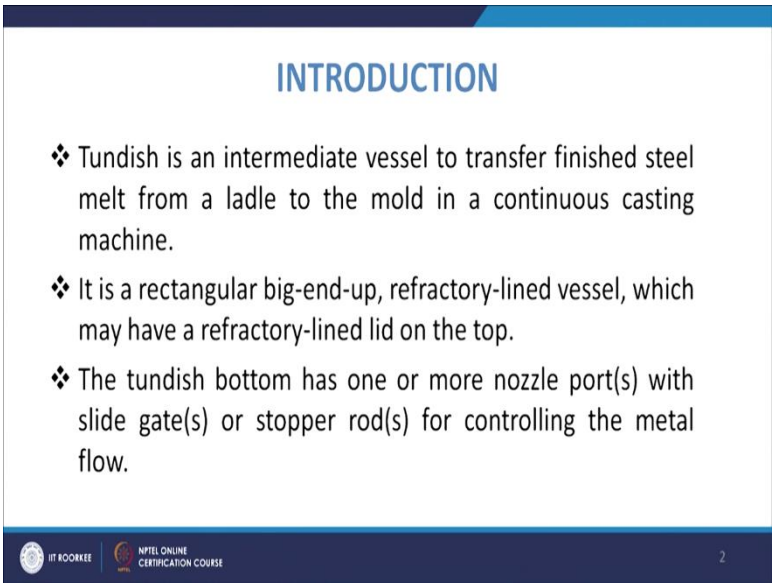

So, it's job is you know that it receives the liquid metal from the ladle and it has to supply the liquid metal to the mold. So, it is an intermediate vessel between the ladle and the mold. Normally it is a rectangular big end up refractory lined vessel which may have a refractory lined lid on the top also.

So, if you talk about a typical tundish; so it is a normally refractory lined and rectangular type of you know vessel. And on the sides, so you have the refractory lining, because you know the steel molten steel is going into it. And certainly it is a metallic structure, because it has to have the rigidity; but then you will have to have the refractory lining, because for sustaining that much high temperature refractory lining is required.

This refractory lining will be basically lost after certain use; so again you have to put the lining or relining is to be done at certain intervals. And also many a times we may have the refractory lined lid also on the top, because from the top you have the transfer of heat to the surroundings. So, many a times we also give the refractory lined you know lid or a cover on the top of the tundish. So, this way your tundish is designed.

Tundish bottom has one or more nozzle ports with slide gates or stopper rods for controlling the metal flow. So, you have the liquid metal going into the tundish from the and you know ladle; but after that you know this liquid metal will be flowing out of the tundish and going into the mold. So, you may have one or more nozzle port with slide gates or stopper rods for controlling the metal flow. Now the thing is that you know, when the there is a outlet portion of at the outlet portion of the tundish; you will have from that portion you will have metal coming out.

Now, the thing is that, when you have a particular bath height in the tundish of the liquid metal, you will have a particular velocity. As this bath height goes on decreasing, as the liquid metal is teemed from the tundish and it is discharged from the tundish to the mold; then depending upon the bath height or the metal head the velocity also may change, velocity will decrease if that level comes down.

So, for you know controlling that metal flow, you have the provision of you know slide gate or stopper rods. So, if you use those rods, you can increase or decrease the metal flow, you know from that nozzle into the mold. So, that is basically to ensure that, there is constant amount of liquid metal which is supplied to the you know mold. So, for ensuring that, you have these you know nozzle ports which are you know provided with these slide gates or stopper rods in the tundish.

So, the job of tundish is also to have basically the uniform distribution of you know liquid metal. So, that will be ensured because of the outlet us being at the same level. And also

uniform flow rate through the you know nozzle and for that you will have the use of these slide gates or stopper rods.

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So, a typically if you look at the schematic of these tundish as we discussed; it will be looking like this that you have this is the ladle which will be bringing the liquid steel, you know from your ever steel has melted and you will may have the you know treatment inside the ladle also. Then this is the ladle shroud; so this liquid metal through the shroud it will be coming and it will be going into the you know tundish.

So, this shroud, this is known as shroud immersion; basically this we do it to ensure that there is no you know direct contact of atmospheric you know gases with these steel which is coming out. So, there may be chances of having a certain kind of oxidation or accordingly you may have the formation of inclusion particles in that case when you have the direct contact of these steel. So, that will be falling into the tundish.

Now once it comes there. So, as you see this is a impact plate or you have a impact pad. Now what happens that, since it is falling and there is a ferrous metal being of very high specific gravity and velocity also. So, it is likely to erode at a very fast rate at these positions. So, what you do is normally in the tundish; you provide there is a impact plate, so that will reduce the you know erosion from these places.

Now what is happening is you may have the you know; now this is your tundish lining. So, this on these sides what you see the yellow structure part, now here also. So, these things are the refractory lining on all the sides. So, the liquid metal which will be coming, it will not be in touch with this the metallic frame; because that will be melted you know in a very less time.

So, you know this refractory lining is done and you know when the tundish lining is seemed to be over; then you have to remove the lining, you have to put the fresh lining. So, that is a continuous process which is going in the case of you know tundish. Then you have apart from that, you have also what happens that you have many flow modifiers in that.

So, the flow modifiers are in the shape of the weir; weir is something which will be coming from the top and the dam will be something which will be coming from the bottom. So, these are basically the flow modifiers or you know they are used basically to alter the fluid flow inside the tundish.

Now we will talk about the role of flow modifiers; one of the role also is to have proper you know fluid flow inside the tundish to ensure many things. And among them the important things are like you should have proper homogenization of the temperature inside the whole tundish.

So, for that you know you use these flow modifiers, because in otherwise if the metal will go. So, it will go towards the bottom directed flow will be there. So, may be that the flow, you will may have a stagnant regions in certain region of the tundish and that fault the dead volume. So, that effectively reduces the volume of the effective volume of the tundish and basically that will also reduce lead to the cold you know regions which will be further detrimental as regards the productivity of the tundish concerned.

So, you have many kind of flow modifiers are there inside the tundish. And among them you have weir which is from the top and you have the dam which is placed on the bottom side and it will be going. Then you have the use of baffles also, so you will have the holes you know; so through that the metal will pass. So, these are the flow modifiers which are used inside the tundish.

Then you may have the use of turbo stoppers which is normally used in the case of tundish. So, these turbo stops are there just at the point where the you know there is heating of the you know liquid stream, metal stream on the tundish bottom. So, that way you have the submerged entry, nozzle which will go in and going into the mold; so that way you have these are the different type of you know components in a typical tundish.

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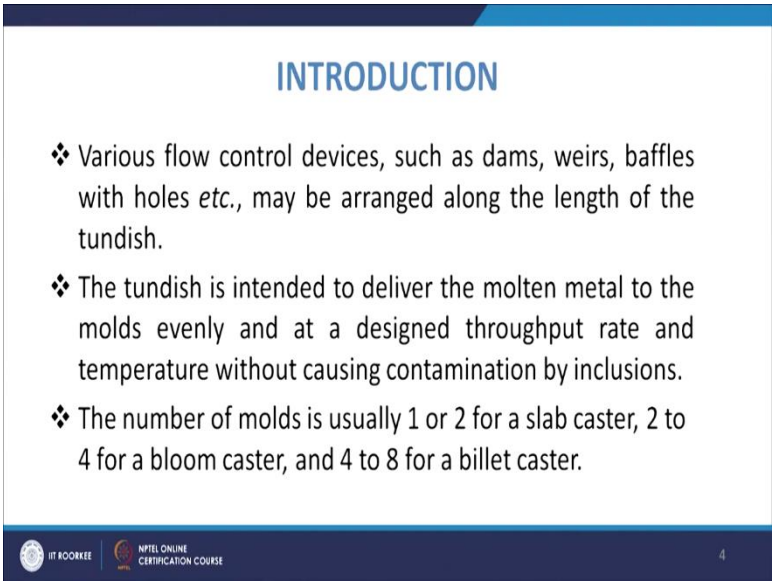

So, as we discussed that you will have the various flow control devices like dams, weirs, baffles with holes which will be arranged along the length of the tundish. And they are basically controlling the flow inside the tundish and you know you can understand it by you know process like if suppose you have a tundish.

So, if the liquid metal will come, so liquid metal will come and it will heat and then it will, it may go like this. So, that may be you know and then; so in those regions or larger portions you may have certain regions where there is not much of the circulation of the hot metal. So, that may lead to the dead regions.

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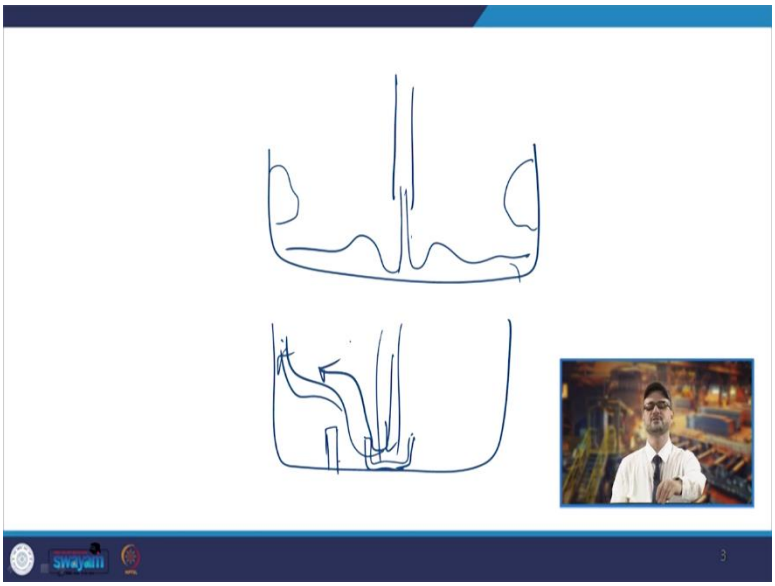

So, what you do is, if you apply you know these you know; so once it hits the liquid metal here and if you apply a dam. So, suppose the metal goes and then it goes like this. So, it may go into this region. So, this region otherwise which was you know dead, which was not very active that becomes active because of these flow modifiers. So, normally we use these flow modifiers, we use also the weirs from the top or we use the you know turbo stop is there at the, this place itself, so the metal will go and moving in this fashion. So, this is how the different type of flow modifiers are used inside the tundish.

The tundish in is intended to deliver the molten metal to the mold evenly and at a design throughput rate and temperature without causing contamination by inclusions. So, as we were discussing that this is the prime role of the tundish; that you know it should deliver the liquid metal to the molds evenly. So, there is a metal should go equally from all the you know outlets of the tundish into the mold; because all the molds are synchronized and they will be oscillating at accordingly and then you will have the dimensions also, normally equal of all these those you know. So, accordingly you can have the variation if required so but; otherwise they are all of equal dimensions.

So, what you need to do is you need to ensure that you are getting even you know, at even rate these molten metal to all the molds at a designed rate throughput rate. And also we and should ensure that the temperature should be you know uniform. So, inside the you know tundish the, there should not be much of the temperature drop you know at two

places. So, this I mean that may lead to other kind of you know flow inside the tundish. And if there is a large temperature drop that is that may lead to solidification in certain results and that will be affecting the space which we you are going to use; that are affecting the you know the utility or the productivity you know as far as the tundish utilization is concerned.

So, and also another important thing is the contamination of inclusions. So, you will have to do something, so that the inclusions contamination is that chance is reduced. So, this is one of the prime rule of the tundish also that it will try to remove the inclusions. Inclusion may come into the tundish or it may be generated inside the tundish. Now the tundish is normally flat, it has a large surface area.

And the flow has to be such by the use of these even sometimes the use of flow modifiers or maybe you may have the design of the tundish in such a manner that; the contamination by the inclusions is minimum the inclusions which are going inside the tundish if any. They must have the tendency to float, to go towards the top surface; where they will be you know they will be there at the top and from in the end you can remove them.

So, that is one of the you know prime you know requirement when we use the tundish. Number of molds may be varying; 1 or 2 it may be there for the slab caster; 2 to 4 for the bloom caster and maybe; 4 to 8 for even the billet caster. So, normally when you have the two molds attached, it will be calling a twin slab caster; we have 2 to 4, so 4 strand or 4 to 8, so 4 strand or 6 strand or 8 strand billet caster. So, this is normally the terminology which we use when we talk about the continuous casting unit in which the tundish outlet is attached to the mold.

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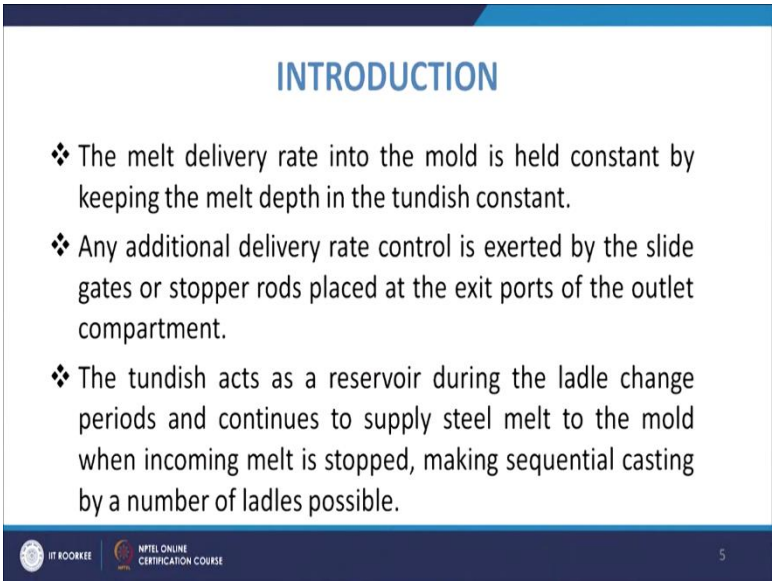

The melt delivery rate in into the mold is held constant by keeping the melt depth in the tundish constant. So, that is what we discussed that we will have to keep in mind that the melt delivery rate should be constant; otherwise it may lead into the you know sometimes over flowing from the mold or maybe your mold becomes dry and the continuous supply is gone. So, that may lead to numerous kinds of defects.

So, you will have to have you know and for that as you know that you have this slide gates or you have the stopper rods available. So, that and to the maximum possible you should try to see that the you know, the surface, free surface level height is nearly constant in that case. If there is no clogging or so, in that case you know it will always be you know the equal delivery rate will be maintained.

Any additional delivery rate is exerted by these slide gates or stopper rods placed at the exit ports of the outlet compartment. We have already discussed that you can have the use of these slide gates or stopper rods. If you feel ever to increase or decrease the delivery rate, you want to control the delivery rate in those cases. Tundish acts as a reservoir during the ladle change periods and continues to supply steel melt to the mold when coming, incoming melt is stop; making sequential casting by a number of ladles possible.

Now, this is where the main role of the tundish is; that it is making the possibility of the sequential casting as we call it as a continuous casting. So, it is because of the tundish that your continuous flowing is flowing of the liquid metal to the mold is ascertained. So, as

you know that the ladle will be receiving the liquid metal from the melting units. And then it will be coming up; so ladle will be pouring the liquid metal into the, you know tundish.

Now once ladle finishes it is liquid metal. Now, in that case this there will be discontinuity. So, and at that particular time there is no, you know supply of liquid metal to the tundish; but in between the even if there is no ladle which is supplying the liquid metal to tundish, tundish is still delivering the liquid metal into the you know mold. So, basically that makes this process a continuous process.

And, because of that only you are calling it as a continuous casting process; because otherwise you will have to stop the process, there is no continuous formation you have to further restart the process and restarting takes you know a lot of time and resources. So, and it is not very easy you know, it certainly it is not impossible; but then it will lead to the decrease of the in the productivity of the unit.

So, basically you know you. So, that is basically known as the ladle changeover. So, when you have the replacement of ladle 1; ladle will go and another ladle will come, so that is process is known as the ladle changeover. So, during the ladle changeover process also; the tundish is you know becoming very very you know effective in ensuring that the there is a sequential casting possible, the power casting still goes on even if there is no supply of the liquid metal. So, that is basically the main purpose of, one of the main purpose of the tundish.

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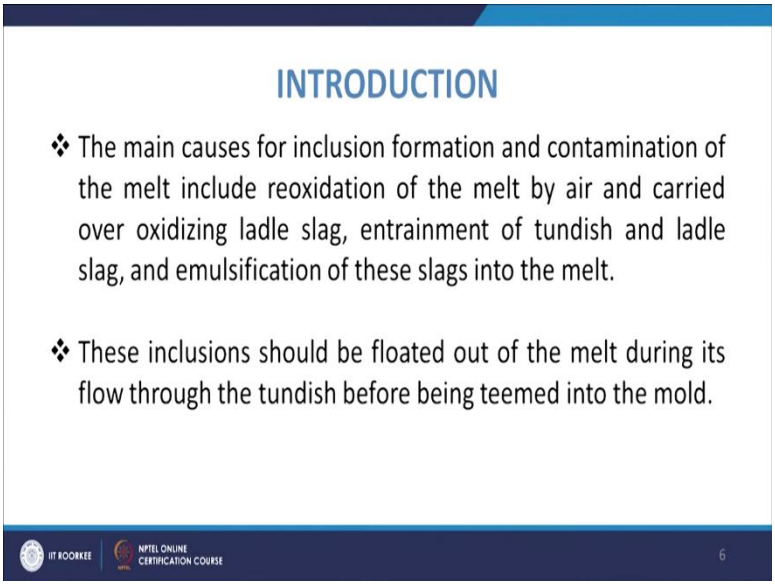

The main causes for inclusion formation and contamination of the melt include reoxidation of the melt by air and carried over oxidizing ladle slag entrainment of tundish and ladle slag and emulsification of these slags into the mold into the melt. So, what we mean by this point is that; what happens that there is large amount of chances of the contamination of the melt, you know and you will have to do something you know. So, that these you know contaminations or this inclusions, so that may be you know by the there may be reoxidation of the melt by the air or there may be you know tundish and ladle slag entrainment is there.

So, there are many possibilities by which you may have the formation of inclusions, you may have deoxidization products or you have the reoxidation; many a times you have the erosion of you know the tundish refractory linings or something is coming from there or something is inside formed also. So, the inclusions may be formed because in the melt itself.

So, you have you know exogenous and indigenous type of inclusions which are formed. So, these you know. So, this is a role of the tundish in that cases to ensure that your these inclusions are basically not going further into the mold; because the tundish is the last reservoir from where I mean after that if the metal or I mean if the liquid metal is carrying any kind of inclusion into the mold, then the situation becomes more severe.

Because in the tundish since being a you know component of very large surface area, free surface area and large vessel. So, you have the chance of having a quiescent type of flow in such a case; you have the chance that the inclusions will be settling and going towards the up, because inclusions are normally lighter. So, although there are chances that they may go you know along with the melt to the mold also; but there are chances if the proper flow is maintained. In that case it will be floating towards the top and then you can further remove these things from there.

So, basically one of the main reason is, one of the main you know function of these tundish is that; you know these inclusions which are there, now these inclusions should you know be separated at that stage itself. Because once it goes into the mold then there are more likelihood of the final product having inclusions and then you will have the rejections of the end product. So, this is the last reservoir where any kind of you know; you where you

can afford to have any kind of inclusion and you can do something, so that these inclusions can further you know be floated.

So, these inclusions should be float out of the melt during it is flow through the tundish before being teemed into the mold; because if it goes further into the mold, then you know that will be the degradation of the quality of the liquid steel melt. And in many cases it can even be you know rejected, so that further you know that will lead to the loss or the decrease of the productivity of the steel maker.

So, that way you know this is the usefulness of this, so you have to design this tundish in such a manner that; the inclusions if there are any the flow control should be such that, if there are any inclusion they should come and float up and most of them should be going at the top where the vessel slag layer. So, they will be captured by them and then you have the you know you have a the, clean steel which is going into the mold and very less chances will be there to have these inclusions further into your final product.

So, that is one of the major you know a function of the tundish. When ladler metallurgy; example the ladler furnace that is LF which was not earlier a fully developed. So, earlier you had the ladle metallurgy or ladler furnace which was not developed; you have a ladle simply it will be bringing and then it will be pouring the liquid metal into the tundish. But when it was not there, there is no ladle furnace, ladle metallurgy was not there, in those cases the tundish role was even more critical.

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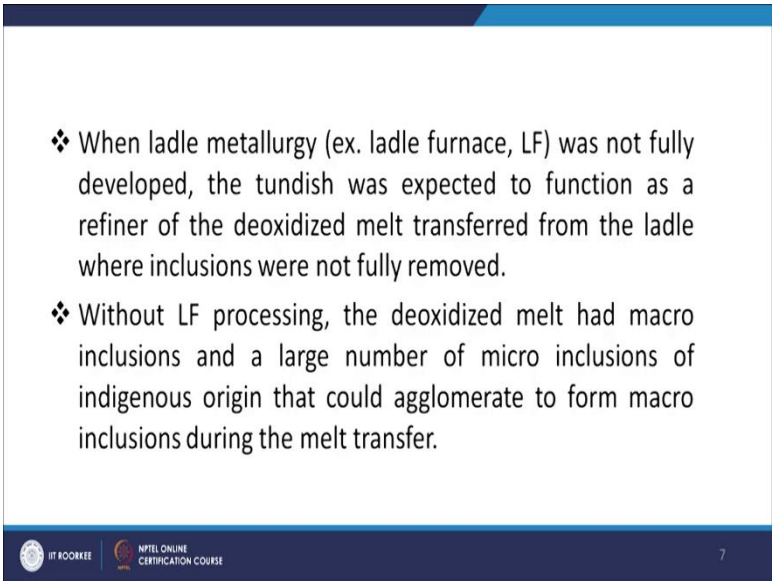

In that case tundish was also expected to function as a refiner of the deoxidized melt transferred from the ladle where inclusions are not fully removed. As we discussed that nowadays you have ladle metallurgy which is coming into picture you have the heating arrangement and then you have the many kind of methods like you have blowing and all that.

By which you try to ensure that there is removal of the inclusions, there is a making of come clean steel into the tundish. But earlier when this was not the practice in those cases you know; the tundish role was more critical. So, it is job was also at the refiner of the deoxidized melt. So, it was you know, so whatever is coming from the ladle or whatever inclusions are coming from the ladle that time the tundish had the additional responsibility of further you know removing those inclusions. So, you know, then they are you are ensuring that it should be removed fully.

Without the ladle furnace processing the deoxidized melt had a macro inclusions and a large number of micro inclusions of indigenous origin which will be formed inside and that can agglomerate. So, that also happens that you have many small inclusions, macro based indigenous inclusions and they will be they have the tendency to agglomerate to you know they have the tendency to segregate. And they will be forming the macro inclusions you know during that melt transfer; and then that will be further you know detrimental, because that will try to have the to go into the melt and they will try to decrease the quality of the product.

So, basically what we mean to say that, you know we discussed that there are different rules of the tundish; one is that you have to control the you know the different aspects. So, if you look at the tundish aspects. So, one will be that it will be transferring the liquid metal then proper you know flow of metal, and then removal of inclusions. In this case you need to ascertain that you have constant delivery, constant you know rate of metal delivery.

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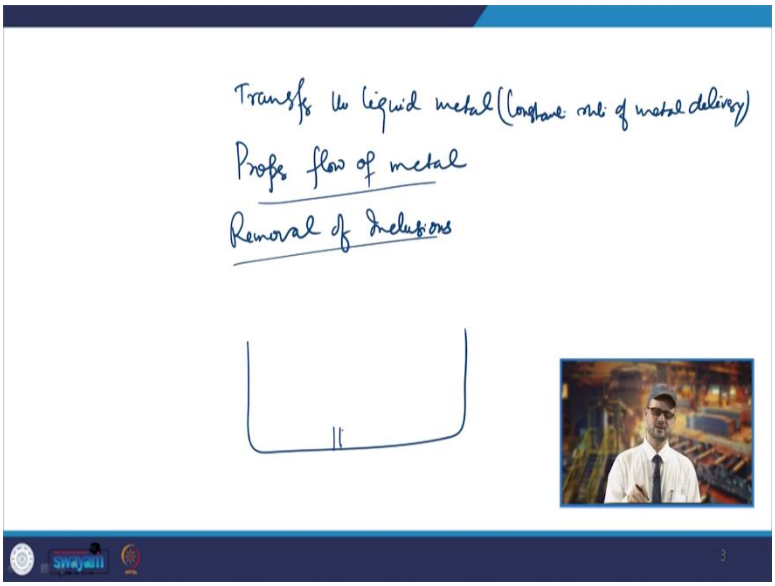

Also what happens that we will be discussing about this that when we have the ladle changeover in those cases also you have the different grades being cached; so there are many aspects which need to be looked into.

Proper flow of metal which is important, because you know many a times what we see that the temperature homogenization is not there; so at one point temperature is less or so, that may lead to you know some other you know kind of flow configuration. And so, proper flow configuration should be there inside; we should see that there is chemical homogeneity inside, there is proper temperature homogenization inside the you know tundish. So, this for proper flow you we use the flow modifiers.

And then for the removal of inclusions, also again here also we try to have the use of flow modifiers or so; but you know in some cases you feel that there should be proper you know mixing of liquid metal you know. So, that there is when especially in the case of ladle changeover, the temperature may be different of the liquid state which is coming from the two ladles.

So, in those cases, it should uniform quickly. And in case of inclusion removal we feel that the flow should be such that there should not be you know more of the mixing kind of things. So, there should be a quiescent type of flow or a flow which is you know which should allow the inclusions to float up.

So, you know. So, we use the different kinds of flow modifiers. And ultimately depending upon what we need basically we try to see that, you know the aim with which this tundish is used, it is basically met. So, all these things are required to be kept in mind. So, with what you know earlier when we had you know the tundish and when we used to have the ladle changeover, so many a times what we used to do is that; we require to stop the caster, because there is another grade of steel which is coming out into the tundish.

So, we thought of or we are going till the last you know levels; level we are decreasing and then next ladle will be going, this is happening when you have the grades of a steel are changing. So, in those cases it becomes you know to understand it is; it is also you know important to see that when you have the different grades of steel coming up how you know the grade which is going inside, how they are going to have a proper mixing in quickly.

So, that has bearing on the quality of a steel which is coming out. So, and also many a times we feel that, the steel which is coming from the next ladle; so it should be pushing of the existing steel into the liquid and then it should have the tendency to come out of the liquid.

So, these are the, you know depending upon that; so tundish has several roles, it is very important part of these continuous casting and it is one must say that, it is one of the most important part of this continuous casting unit. And you must have the proper knowledge of the technology which is there it because of the tundish; that is not unknown as tundish technology. And what way it is affecting the overall quality, overall you know a cleanliness of the steel by you know properly you know managing the fluid flow inside the tundish.

You know and also ensuring that, the melt quality or melt temperature is uniform all together all this. So, this is about the, you know role of tundish in continuous casting. We will be talking more on the, you know tundish in our coming lectures.

Thank you very much.