Modeling of Tundish Steelmaking Process in Continuous Casting

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Lecture - 04
Components of Continuous Casting Unit

Welcome to the lecture on Components of Continuous Casting Unit. So, we will be talking about the different essential details and the components of the continuous casting unit and we will be talking also about its significance in the continuous casting process.

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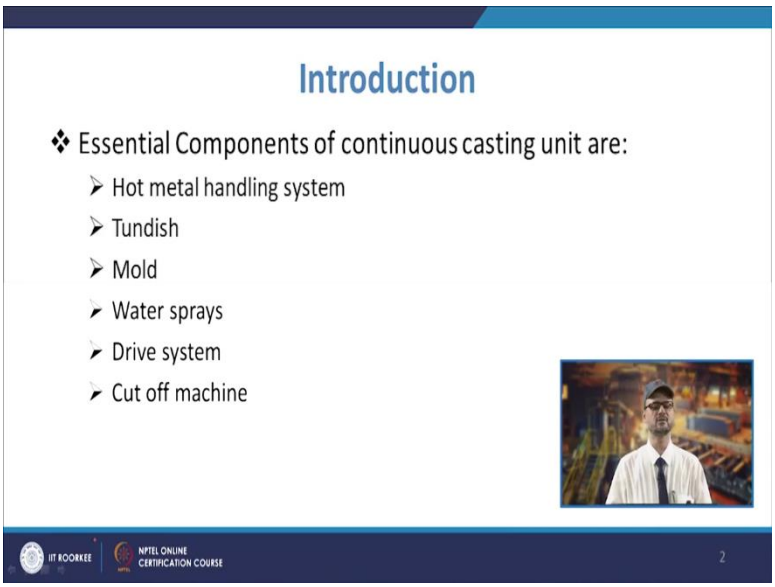

So, as we move on we will talk about these following components like a hot metal handling system, then you have tundish, mold, water sprays, drive system and then cutoff machine. So, all these you know system , all these components make one continuous casting unit and a hot metal handling system is it will start from the you know that system which will be handling that hot metal, it will be bringing that hot metals that is especially the ladle.

Then, the ladle as we know that ladle, from ladle the metal will be transferred to tundish and then to the mold and after mold, you have the you know spray zone. Water spraying is done, then you have the driving system and then further and the end you are cutting off. So, you have a cutoff machine. So, we will be talking one by one about these systems.

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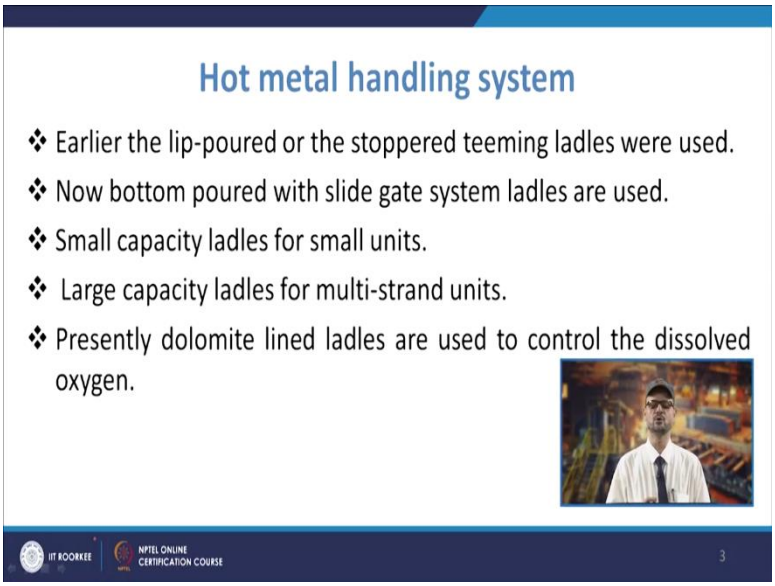

Coming to the hot metal handling system. So, as you know that it brings the hot metal and it its job is to pour it into the tundish. So, earlier the lip poured or the stoppered teeming ladles were used. So, that was the practice earlier , but now most of in most of the cases bottom poured with a slide gate system you know ladles are used.

So, you will have the metal coming from the bottom and then, you will have the slide gate for controlling that flow of the liquid metal. So, you will have a slide gate and by operating that you can allow the liquid metal to fall from the ladle into the tundish.

Now, a small capacity ladles are used for the smaller units and there will be larger capacity ladles will be there for the multiple strand systems like when you have a the single strand tundish. Then, you need the small capacity ladles which will be a smaller in sizes. However, if you have the you know multi strand tundish; multi strand you know six-strand, four-strand or so or eight-strand even in those cases you know we use the larger capacity ladles.

Now, presently what we do is we normally use these dolomite line ladles you know to control the dissolved oxygen. So, what has been seen that you know you may have the lining with dolomite or you may have the lining with bauxite, you may have even the lining with the silica and it has been seen that the ppm of the oxygen which is observed in the case of a dolomite lined ladles or even the bauxite line ladles, they are lesser when the and the observation has been found by Tata steel.

So, it was that it was about 2 to 6 ppm of oxygen was observed in the case of dolomite you know lined ladles and then, it may go a little bit higher when you go with other you know like silica lined. Then, you know the oxygen level. So, what has been shown this is a typical you know it is about 10 to 20 ppm in the case of silica line ladles.

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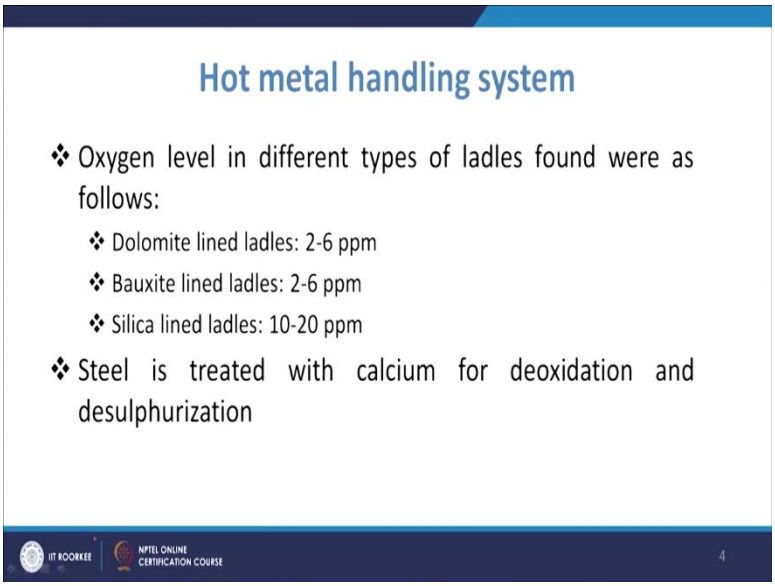

Now, steel will be treated with the calcium for the deoxidation and desulphurization. So, in most of the cases, we tried to have the minimum amount of oxygen as well as sulphur is also deleterious for the quality steel. So, we also try to treat with the calcium for the deoxidation and the desulphurization. So, that is what is normally the practice for the you know in the industries by using the calcium.

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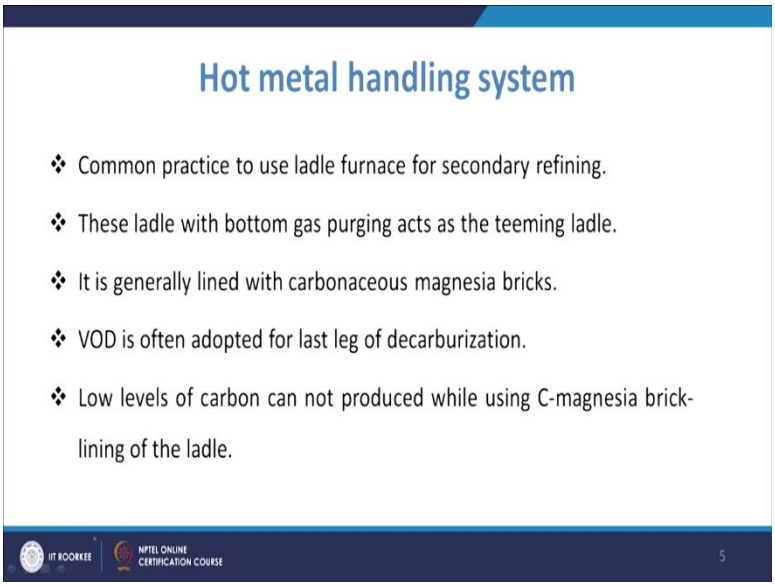

Common practice to use the ladle furnace for secondary refining. Now, what we have earlier seen that nowadays it is a very common practice to use the ladle furnace. So, that is a very important tool for the secondary refining process and in that basically you have these ladle, with the bottom gas purging. So, you will have the purging from the you know bottom the gas purging is done and that acts as the teeming ladle.

Now, it is generally lined with carbonaceous you know magnesia bricks. So, that is the normal practice. Now, when we tried to have even the smaller amount of carbon or so; so you know for that for the decarbonization, many a times we use the VOD process also. And you know while also using the magnesia brick lining of the ladle, then also we can ensure the low level of carbon you know that is what is found to be.

So, that is a the part you know so that is the first part. So, because the ladle will be bringing and then, ladle you have the that taken also be used as ladle furnace. So, you will have the ladle which is also lined. You can have you know the you know the lining with different materials and you know earlier the practice was that many type of treatments were done in the tundish also. But now tundish will be simply acting as the reservoir.

So, normally this you know this is about the hot metal handling system. Now, we come to the next stage that is your you know tundish. Now, in the tundish as you see that tundish will be that vessel which will be after that you know ladle. So, the tundish will be receiving the liquid metal from the ladle and then, it will be distributing it or it will be passing that

liquid metal to the mold. So, as you see that the tundish will be necessary to team the steel from the ladle to the mold.

It acts as a buffer vessel between mold and the ladle. Buffer vessel as we have already discussed that will be the vessel which will be supplying the liquid metal whenever even in the case of ladle changeover. So, one ladle when gets emptied, then when the that ladle is removed and the next ladle comes to supply the liquid metal to the tundish. So, in that situation, even the continuity of the liquid steel from the tundish with a mold is maintained.

So, that is why it is known as a buffer vessel between the mold and the ladle. Now, it maintains the casting continuity. So, as we have already discussed that even if there is no ladle, it will go on a you know having the there is will be continuity in getting the liquid supplied from tundish to the mold.

So, the casting continuity will be maintained. It improves the yield because you know from there it is going directly to the mold and where you are getting the finished product. So, that way you know many a times now in most of the cases what you would normally do is we try to preheat the tundish because the tundish which is there at room temperature and if you are initially supplying the liquid metal to the tundish, then they are maybe temperature drop in the liquid steel and that may affect the quality of the steel. So, in most of the cases you are preheating so that the heat loss which will normally take place that will be minimized you know in those cases.

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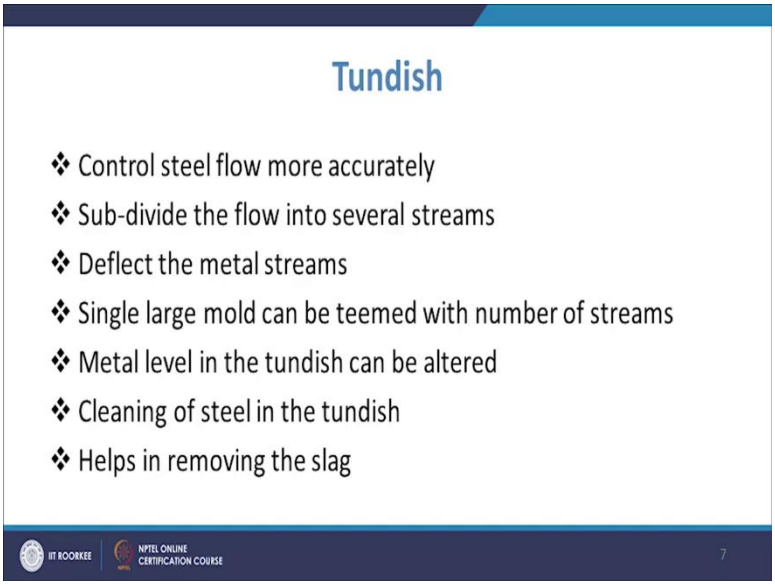

Then, the tundish will control the steel flow more accurately because you have the you know controlling mechanism and you are basically you know you are controlling that so that the constant amount of liquid steel should fall into the ladle.

So, also because it has a very large surface area and in that case normally you know during the changeover also, there will be very small decrease in the height of the free surface of liquid metal in the tundish. So, they change in the velocity will be very very small.

So, basically the steel flow will be controlled more accurately because of the tundish. Now, this tundish also will be subdividing the flow into several streams. So, what happens that when the liquid metal will be going.

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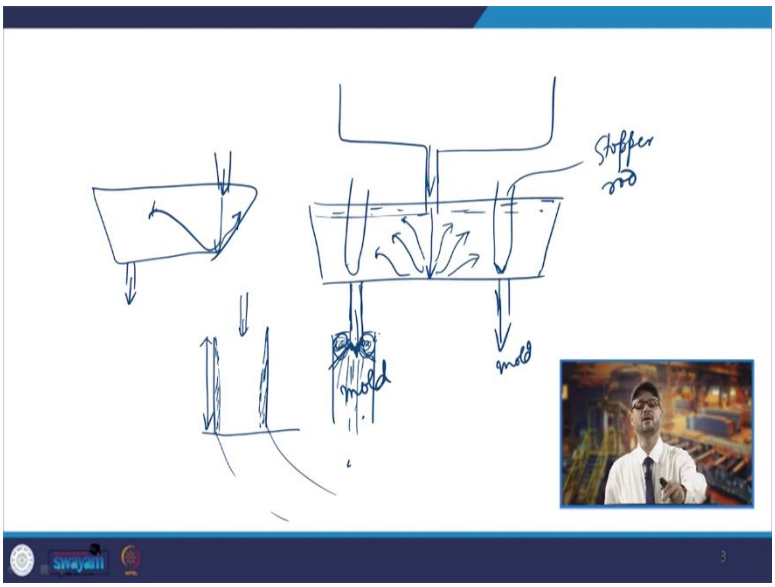

So, when as you see that in the case of. So, you have a initially you have the you know ladle and then, you will have a tundish. So, this will be your tundish in fact.

And in the tundish you know this is, so this will be. So, there will be entry of liquid metal from the ladle into the tundish and then, you have these are the you know outlets. So, these are the exit ports of the tundish. Now, in normal case you know you have you know this is this is how one stopper rod is also there.

So, this is a known as a stopper rod. So, this is stopper rod basically as we had discussing that this will be controlling. So, you can put this stopper rod in this zone. So, that will

regulate the flow of the liquid steel to the mold. So, here from it is going to the mold, it is going to the mold here.

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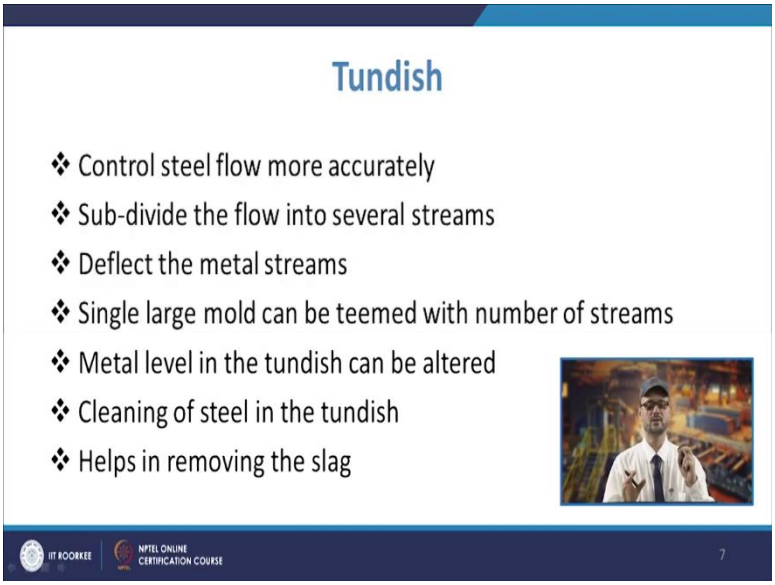

So, basically you have you know this way it controls that you know the I mean quantity of metal which is flowing into the mold. Now, coming to talk about the dividing the flow into several stream. So, what happens that when the flow will be coming here and when it will be striking; so metal will be going from here like this and it will be going like this from here. So, this way it will be moving to in the different streams, the metal will be going.

Now, you have the you may have two-strand, you may have four-strand or six-strand. So, this metal is divided into different streams in different directions depending upon the even the configuration of the tundish also. If you have a tundish suppose you have a you know tundish and you have the inlet here only and your outlet is only here, in that case anyway liquid metal with the heat here and then, it has to move in this case. So, there will be some movement this side also.

But otherwise if you are hitting in the middle portion, in that case you know it will be divided into different streams and then, it will be moving towards the different outlets on the on both the sides of the you know inlet stream, where it is striking the tundish bottom.

So, that is the job of you know the tundish also that it will be dividing that stream. Now, it will be deflecting the metal streams as the same thing because once it will come and then

you know it is going towards the wall and because of the wall of the tundish, it will be deflecting from there and it will move towards the outlet. The ultimate is that in an optimal manner with a proper flow configuration, the metal which is entering into the tundish, it has to move towards the outlet.

Single large mold can be teemed with number of streams. So, you know that is possible because you may have different streams and by that if you have a large mold, then it can be teemed with the number of streams.

Metal level in the tundish can be altered you know because I mean it is altered in the case of you know ladle change over normally and which seems that you know the level you know whenever many a times our job is also to I mean in earlier times in our earlier times, when we are talking about initial days when you have to cast different grades and you have only one tundish. So, in that in those cases you have to you know decrease the level of the material in the tundish and then, for that you have to start filling it.

So, so that way you know you can do that in the tundish. So, it will go to certain lesser height and then, further you will start filling it with the ladle. So the next grade will be started filling.

Then, you have also the possibility of you know the cleaning of a steel in the tundish. So, many you know in the past also it has been seen that there are sometimes the cleaning operation is also done in the tundish, you have and even now because we think of having the tundish to act in such a manner that if there are any inclusions, they must float. So, the inclusions must be removed from the steel in the tundish.

So, it also works as the reservoir which will be looking towards you know minimizing the inclusion content in the steel. So, that we will see you know later. Now, it will also help in removing the slag because you know a slag if the there are. So, they will be floating at the top.

So, if the slags are a you know entrained. So, because of the flow quiescent flow inside which can be maintained, you can allow the slags also to normally in the normal circumstances, the slag will be at the top and these. So, beneath that there will be molten liquid so that way, it will be you know we also have the you know get the help in removing the slag also.

So, because it will be at the top portion and the we are taking the liquid, you know so slag will be towards this stop portion and and liquid metal is teemed from here. So, it will be delivered to the mold from here. So, anyway that that slag does not cause any harm and it will be delivered to the mold.

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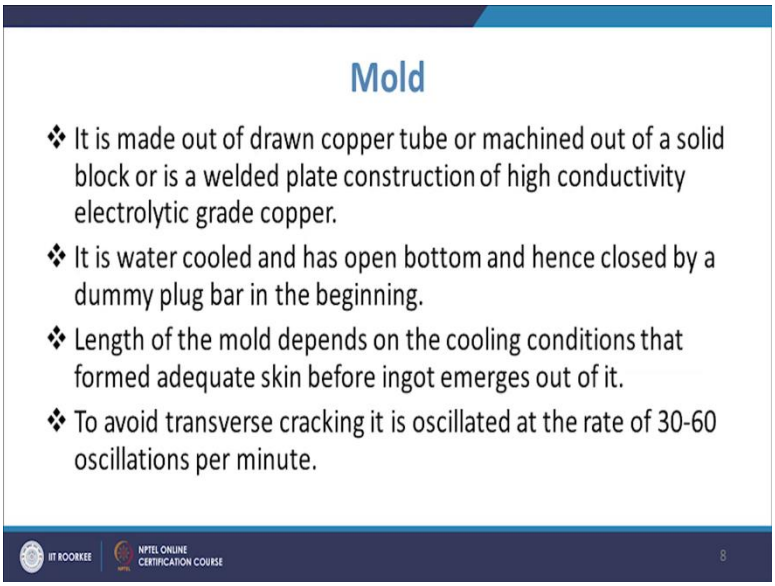

So, then you know the metal comes towards the mold. Now, we all have already discussed that we these mold is made of the drawn copper tube or machined out of a solid block or is a welded plate construction of high conductivity electrolytic grade copper.

So, the mold in the case of a continuous casting is made with the high grade electrolytic grade copper and copper is chosen for the obvious reason that it has very high conductivity and it can you know remove the heat of the molten metal very fast.

So,, but then as you discussed that since the melting temperature of copper is small, I mean smaller as compared to us less as compared to that of steel. So, we need to have the invest other cooling mechanism constantly so that it can take the heat away quickly and it should not melt also and for that, it is normally water cooled and has open bottom and hence closed by a dummy plug bar in the beginnings.

So, essentially in the beginning we close it. It is a dummy plug bar and then, normally it will be have open bottom and then, water will be coming and flowing. And during that process, that water will be absorbing the heat which will be released by the liquid metal in

the mold and then, it will be that. So, the water takes the heat and then, thats why you will have the change in the temperature of the incoming water and the outgoing water because that water will be taking that heat which is being released by the mold.

Length of the mold depends on the cooling conditions that formed adequate skin before ingot emerges out of it. So, this is very important that what should be the length of the mold and that will be depending upon the cooling conditions. The cooling conditions has to be such that you know the adequate skin is formed before the ingot emerges out of it.

So, as we have a you know seeing that in the case of a mold when the liquid metal will be you know poured through it. So, it will be started you know forming the skin and this skin you know thickness, the shell thickness will go on increasing on both the sides. Now, the thing is that when your what should be the height of this mold?

So, it has to have you know at such a place so that to ensure that there is a skin you know freezed of certain thickness and then because it has to further come and then, it has to move on the rollers and further, it has to you know move you know and finally, it has to be in horizontal direction.

So, there is a lot is a amount of pressure of the liquid steel for a static pressure is there. So, you ensure that cooling. So, that a skin of adequate thickness is you know developed at the end of the mold. So, that has to be ensured. So, that is what it will be the requirement in the case of a mold. Also it will be avoiding the transverse cracking; you know it is oscillated at the rate of 30 to 60 oscillations per minute.

So, what is happening we have already seen that you are giving that oscillation; for a certain region you have you are giving the negative strip. So, it has to leave that mold and then. So, yeah that oscillation and also in the mold, we are giving the you know lubrication.

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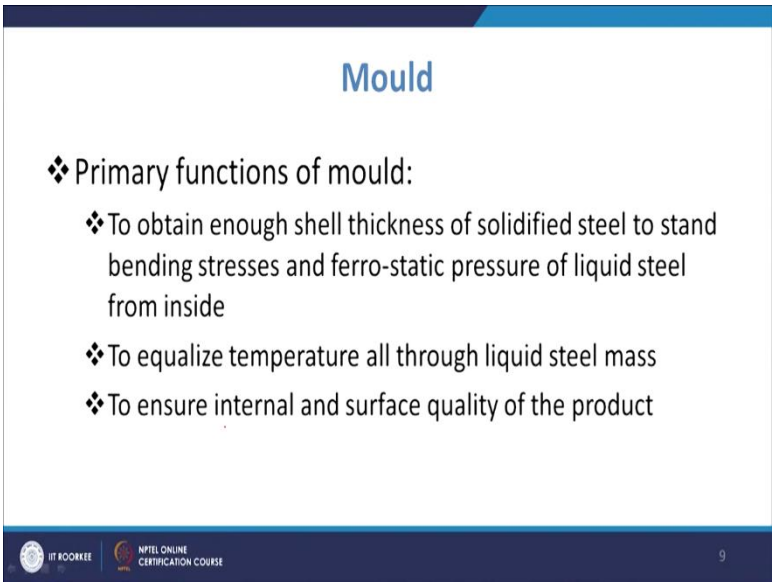

So, if you talk about the function of the mold, it is to obtain the enough shell thickness of solidified shell to stand bending stresses and ferro static pressure of liquid steel from inside. So, what we see nowadays we have seen that also you are mold is from there itself, it is somewhat curved. So, you will have the bending stresses and also you have the ferro static pressure of the liquid steel.

So, the you know the shell thickness which should be achieved at the exit point of the mold that is your primary cooling zone, it must be adequate to bear you know to strand these bending stresses as well as the ferro static pressure of the liquid from insight. Then, it is also job is to equalize the temperature all through the liquid steel mass.

So, it must ensure that there is a proper temperature, otherwise there may be different structures on different sites and that also ensures internal and surface quality of the product. Because there are likely to have the and generation of cracks or other kind of defects because of the improper cooling conditions in the mold. So, there also it is ensured.

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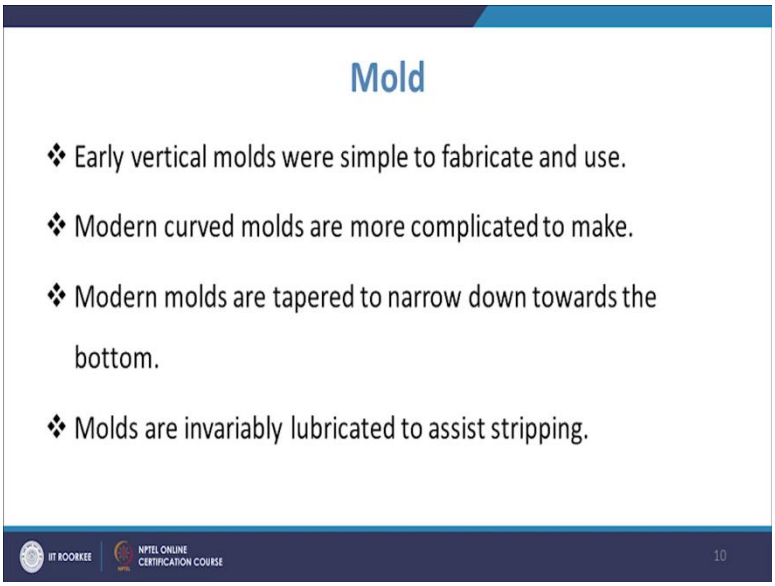

So, you have earlier vertical molds, then you we get nowadays the curved molds which are complicated and modern molds are tapered to narrow down towards the bottom and its basically to account for the shrinkage. Because when we know that you know there is tapering which is done because the metal which is getting solidified and it has a higher density. So, there will be shrinking of the metal and to account for that there is some taper which is given you know the in the mold to account for that.

So, that is another you know since your calculation which needs to be done, you know to avoid any kind of defect in the case of continuous casting. They are invariably mold is also invariably lubricated to assist the stripping. So, as we have discussed that there will be some lubricating mechanism, which should be there in between the mold wall and the liquid metal which we get's solidified in the skin. So, that they are should not be sticking and then, there is a proper stripping of that product from the mold so that also is ensured by having the choice of proper mold lubricants.

Next comes in the line will be the Submerged Entry Nozzle. Now, the submerged entry nozzle is the ceramic tube which has a closed bottom and it is connected to the tundish at one end, while the other end is a dipped in the molten pool in the concast mold.

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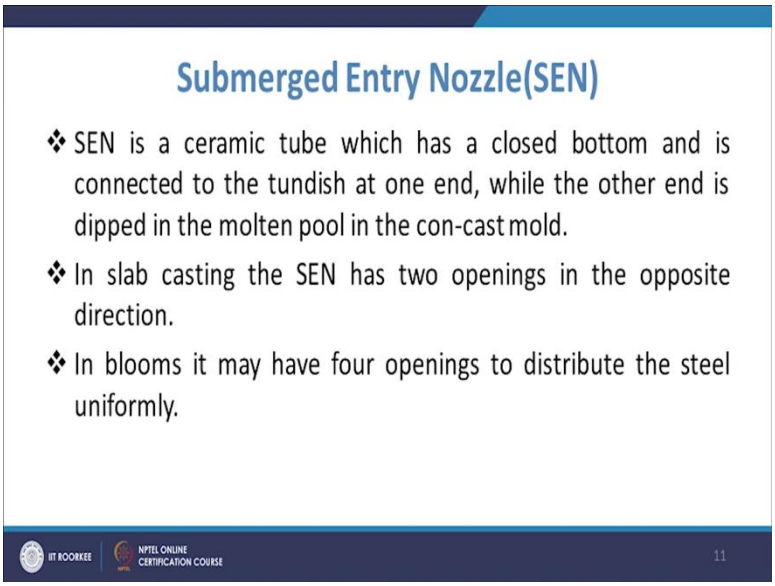

So, that is basically you know if you to talk about the tundish, so from here this will go and this will be submerged entry nozzle and then, it will go into the mold and here, it is closed and you have opening on these sides. So, this way you have this is your submerged entry nozzle.

So, in the slab casting this SEN has two openings in the opposite direction and in blooms it may have four openings to distribute the steel uniformly. So, it may have a you know depending upon what you are casting, you may have either two openings or four openings to distribute in the steel because from there it will come.

So, normally when you if you look at the you know liquid. So, it will go and then it moves like this; it will strike here some will go up and then some will go down. So, like that liquid metal will come and so, you will have a loop also farmed here in many cases.

So, that is you know because of the submerged entry nozzle which is there which is a closed from one end and another end will be you know from the tundish it will be coming down. So, it is on the one end on tundish, another is in the mold..

Now, coming to the submerged entry nozzle, you know organ gas is used to prevent the sticking of a steel to the SEN surface and aspiration of air through the tube pores and joints so that is normally the practice that you are using this argon gas so that the SEN surface is not stuck to the steel and also the there is a you know a aspiration of air.

Mainly, Al_2O_3 and C is used as the base material for making the SEN and also you may have the zirconium oxide carbon is also in many case it is used. The main problem of using the SEN is that it gets clogged due to the accumulation of alumina from inside. So, many a times the alumina which is coming you know because of that there may be clogging in the SEN and that will be leading to decreasing the flow rate causing problems in solidification of a steel in the concast mold.

So, that is a really a challenge because if there is clogging, then there will be decreasing the flow rate of the steel which is coming through that SEN ports. So, that is another challenge and that is because of the inclusions or alumina which is you know accumulated. Mold lubrication; so, mold lubrication is you know earlier you had the moisture free rapeseed oil was used as the more lubrication, as we had discussed that you have to have something a lubrication so that there is no sticking.

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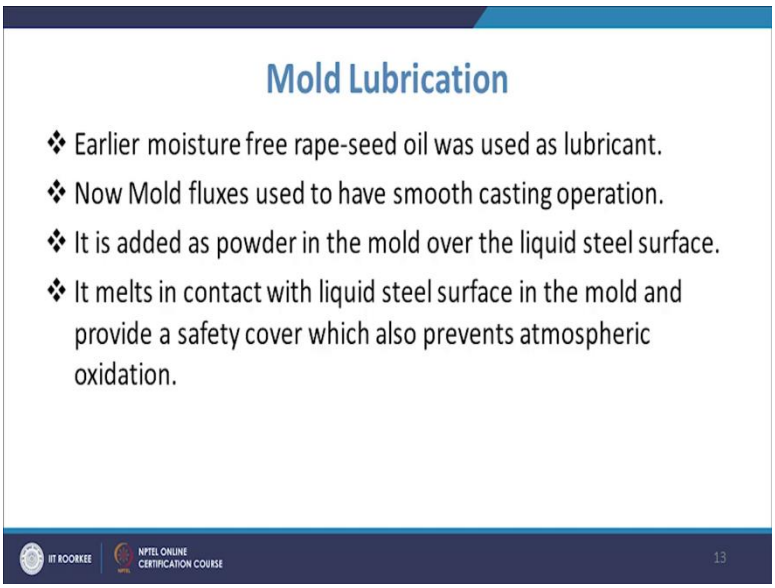

Now, we have mold fluxes are used to have these smooth casting operation and it will be added as the powder in the mold over the liquid steel surface. So, we. So, there is a normal practice you have a powder which will be given out the surface.

And when it will be coming in contact with the liquid surface, it will be melted and then, it will be going in between the mold wall and. So, there will be a layer of that lubricant and that will allow you know that will ensure that there is no sticking of this surface. And

also the another advantage is that it will be preventing the you know oxidation to take place from atmospheric air. So, this is the example of these mold flux powders.

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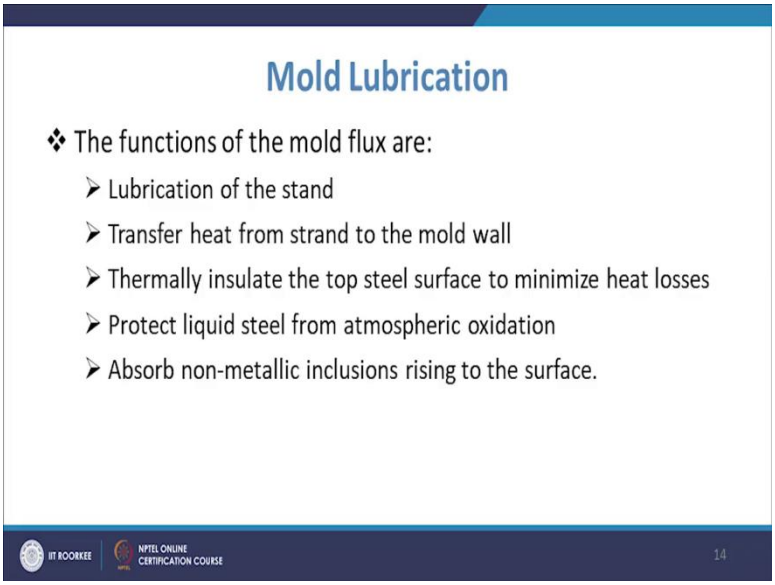

Then, the function of these mold flux are that there will be lubrication of the strand. Then, you have transfer heat from the strand to the mold wall and then, thermally insulate the top steel surface. That is what we have discussed.

Protecting the surface from atmospheric oxidation and many a times, it will be absorbing the inclusions because inclusion if they go up so that powder, they will be attracting those inclusions, that is another advantage of these more lubrication mechanism.

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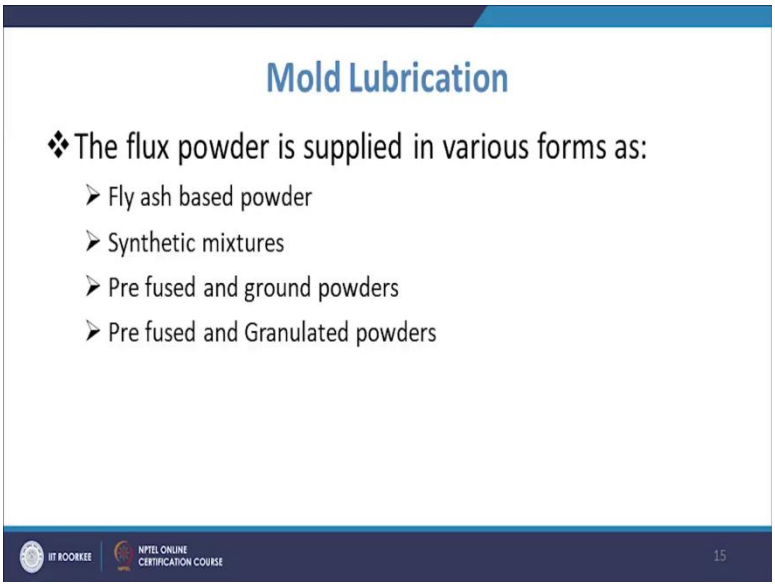

And they are in different forms, we use it like fly ash based powder, synthetic mixture, pre fused and ground powders and then, granulated powders also. So, that way we give these more lubrication.

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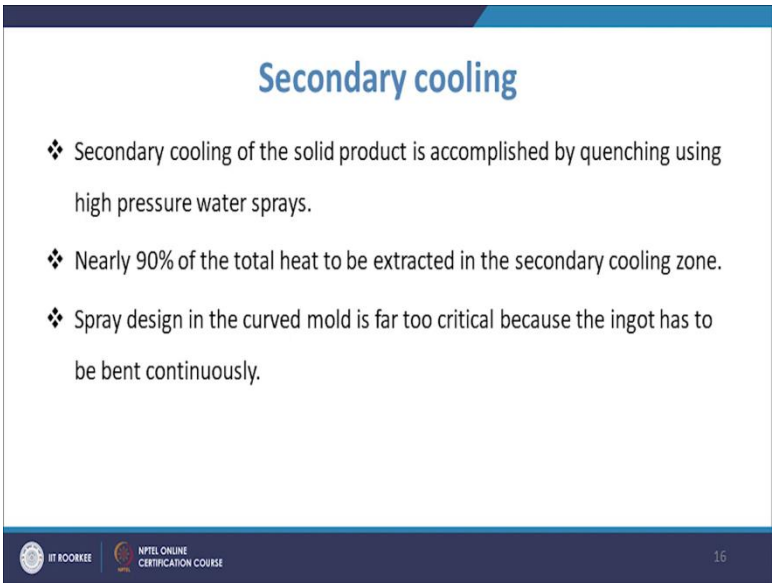

After that you have the secondary cooling of the solid product and it will be accomplished by quenching using high pressure water sprays. So, we are using those hotter water sprays and then, require the cooling is done.

So, 90 percent of total heat is the to be extracted in that secondary cooling zone after the mold that zone starts and spray design in the curved mold is a far too critical because the ingot has to be bent continuously. So, there also it is bending, so it is a another challenge that it is bending. So, you will have less area here more area.

So, properly you have to have the cooling so that you know the uniform structure and uniform properties are to be ascertained and then finally, it will go and then ultimately, we are cutting it once we ensure that it is completely solidified. So, you will have a cutting torch and that will be cutting it.

So, these are basically the you know the components of the continuous casting units and you can study more from the reference and textbooks to have more understanding which will help us to discuss you know more on the issues in our coming lectures.

Thank you very much.