Modeling of Tundish Steelmaking Process in Continuous Casting

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Lecture – 01
Introduction to Continuous Casting Process

Hello friends welcome to these MOOCs online course on Modeling of Tundish Steelmaking Process in Continuous Casting. Let me introduce myself I am Pradeep Kumar Jha associate professor in the department of mechanical and industrial engineering at IIT Roorkee. So, we will be there together for these 20 hour course on Modeling of Tundish Steelmaking Process in Continuous Casting. Coming to the introductory lecture and the lecture number 1, first of all we should talk about the terminologies related to this course that is modeling of tundish steel making process in continuous casting.

So, as you know modeling means we will be talking about the modeling aspects especially the physical modeling as well as the numerical modeling aspects, then you have tundish steelmaking. So, we will talk about the role of tundish and how you know the there is flow inside the tundish and how it is role will be there towards the different metallurgical operations during the continuous casting process and I hope that you are conversant with this term continuous casting.

So, coming to the continuous casting first as you know that the casting in casting process you have the solidification of liquid metal in a mold and in conventional casting when you cast in a sand mold or in a suppose metal mold. So, in sand mold as you know that the cooling rate is smaller one so, you have you know the limitation of having the very fine grains of the casting.

So, and accordingly the there is reflection of those things on the properties of the casting. So, for even better properties we go to the metallic mold that we known call it as the dye casting you have gravity dye casting or you have the pressure dye casting. So, these are the normal casting processes and you must have the idea about the different types of casting processes like you have the investment casting, you have lost form casting.

So, there are numerous you know types of casting processes, but why continuous casting is very much in demand, why the continuous casting is so important nowadays? If you look at the you know the scenario today most of the modern steel makers they have continuous casting unit and most of the products are you know made using that continuous casting cast product you know made like we make these slabs blooms or billets from continuous casting and then they are further converted.

Now, why this continuous casting why there was need to go for the continuous casting and what are the traits about the continuous casting process, in this lecture we are going to discuss about those things.

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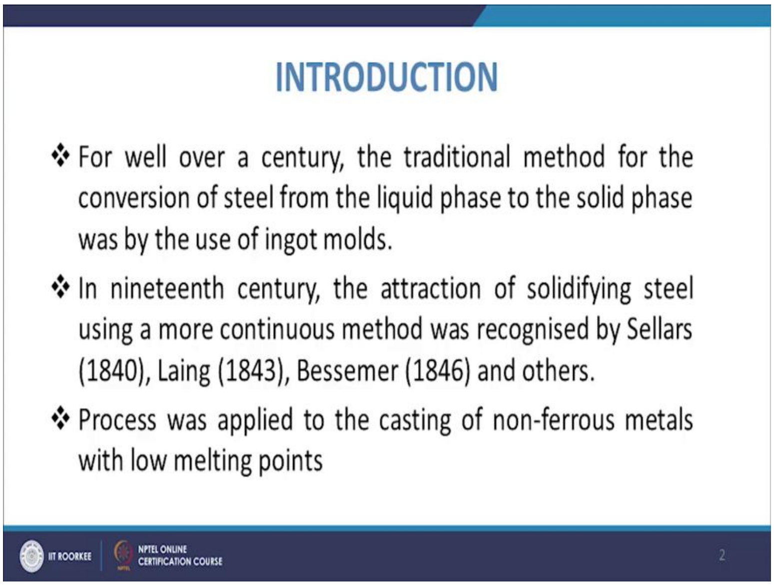

So, for well over a century, the traditional method for the conversion of steel from the liquid phase to the solid phase was by the use of ingot molds. So, as we discussed that in normal you know casting process, you have a conventional mold, you have a finite sized mold you know small size mold and you try to pour you know by from the furnace with some mechanism you pour the liquid metal into that mold and then you allow it to solidify.

So, in case of sand mold you are allowing it to solidify in normal conditions and in case of metallic mold you are applying. So, in a in case of metal molds is the thermal conductivity of the mold is higher. So, it will solidify fast further some we also use pressure to you know to assist that solidification process. So, this is done in the case of normal process.

If you talk about the industries in industries you have to make larger slabs. So, in earlier times you had the process of making ingot molds. So, ingot molds where of larger dimension if you talk about the ingot mold. So, it will be something like larger sized you know molds are there so, they are ingot molds. So, the metal will be poured into it and then the ingot will basically so, this will be solidified.

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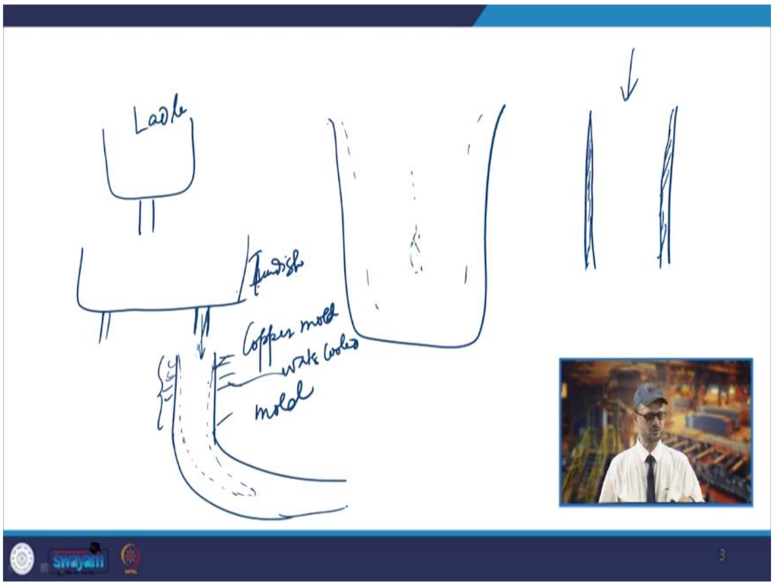

Now, once solidified once it is a so, there are solidification will start from all the sides this way and then this ingot will be taken for the further processing this ingot will be taken to the slabbing mill, that it will be going to the rolling mill, you have hot rolling then you have cold rolling. So, there are many processes which it has to undergo.

And if you talk about the production of a thin sheet of steel then you know all these processes have to be done. So, this ingot is to be taken out it is further to be heated then it is cross sectional it is dimension is to be reduced, you know in the different types of mills and for that there is you know there is quite intensive requirement of the energy you have to heat it you have to you know and if during some process if the heating process is not complete you have to further heat it. So, all these things are to be done and it is a quite a time consuming and energy intensive process.

Now, this was, but we had we did not have any way out and this was only the way by which you have to make you know the flat products like slabs or seats or so, that was the you know earlier process. So, that was for well over century this was the traditional method for the conversion of a steel from the liquid phase to the solid phase and there are many challenges basically in that process because what happens that you had to go to these mills you have to take these ingots to those mills because of many reasons because what happens that you know because of the very large sizes you have you know different types of grain structures not very much always preferred you know grain shapes and sizes and orientations too.

And also you are likely to have you know centerline maybe shrinkage towards the centerline maybe also there is you know solute registration kind of defect also is likely to be there. So, and also there will be certain other kind of casting defects so, you have to get rid of these. So, you are going to apply the forming pressure you have to apply the compressive forces and then you have to ensure that all these defects are gone when while you are making these cast products.

So, you know for that and also since it was very much you know there was very much requirement of the energy for that process. So, you know in the nineteenth century the attraction of solidifying steel using more continuous method was recognized by sellers in 1840 Laing in 1843 and Bessemer 1846 and even others later on. So, basically this was you know that was in a continuous method they devised some means to you know to do the solidification of a steel well you know.

And initially basically process was applied to the casting of non ferrous metals with low melting points you know because of certain obvious reasons like you know the temperature was larger in case of ferrous castings and also the conductivity issues in case of ferrous materials. So, initially it was you know limited to the non ferrous materials especially they are lighter.

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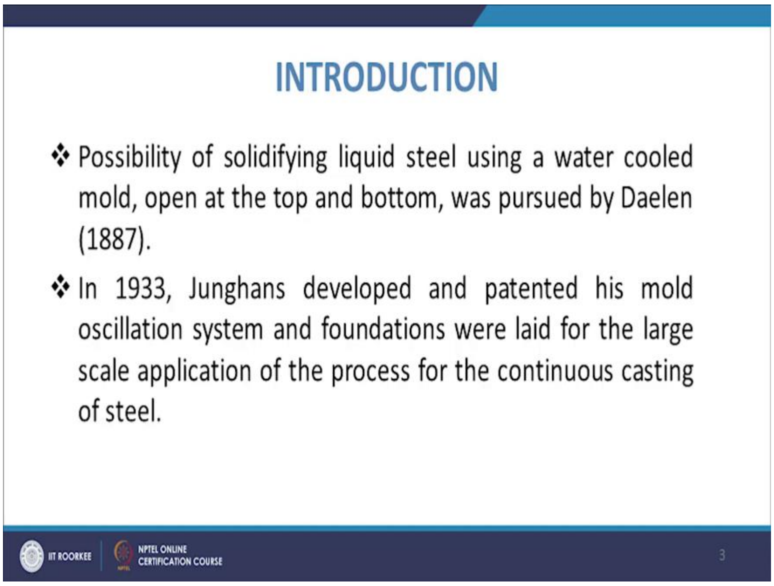

Now, the possibility of solidifying liquid steel using a water cooled mold opened at the top and bottom was pursued by the Daelen. So, in 1887 if you if you look at then it was seen that this was you know exploited that whether there is an impossibility of solidifying liquid steel is there.

So, in that what happened that you have a mold which is you know water cooled and this is also open at the top and the bottom and this was done by the Daelen and that is basically the working principle of continuous casting. Where you have a mold basically which is made of normally copper and you are allowing the liquid metal to flow from the top and this liquid metal goes from the bottom and then there is a cooling of this mold from all the sides by water. So, that was basically the this was done by the Daelen in 1887.

Now, when this method was devised so, in that case there are many challenges initially and one thing was sure that once you are you know putting the liquid metal from the top and if the mold is cooled by water from outside then certainly there is will be immediate solidification taking place from the sides. However there were challenges related to you know the sticking and other things.

So, for that you know in 1933 Junghans he developed and patented his mold oscillation system. So, you know their challenges was that one is that the strip you know the solidified cell which is there on the sides. So, what is happening is that, you have the open you know top and bottom and you are pouring the liquid metal. So, what will be happening, it will go and get solidified. Now, the thing is that this is solidified layer and basically it has to leave it has to come continuously downwards otherwise there will be constant you know layer. So, this will be fixed only and it cannot go further.

So, you had to do something so that it should come down. So, you should leave also this. So, for that the oscillation system was there and also you know there was another mechanisms that there should be something in between these 2 interfaces so, that it should not allow it to you know get stuck.

So, basically they thought that you should have the oscillation system and that was the that was the time when the foundations were laid for the large scale application of the process for the continuous casting. So, in that basically from there you can say that it was full fledged type of you know design of the continuous casting system which was into the world.

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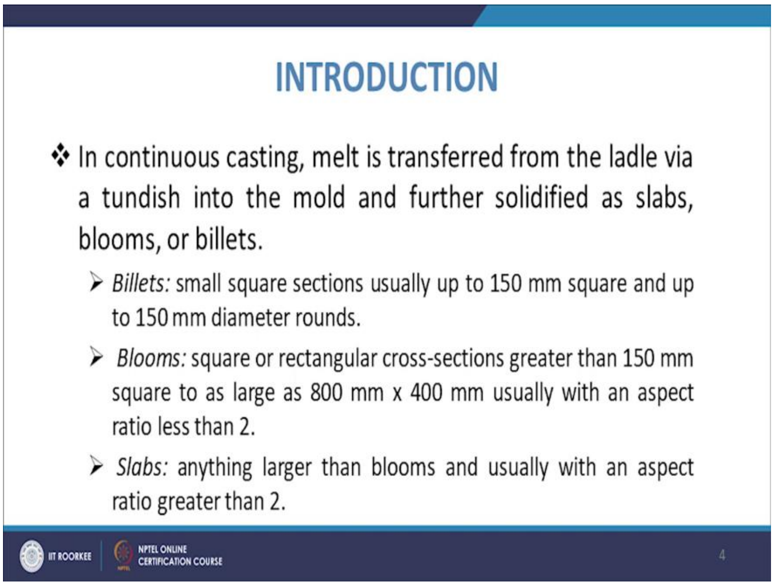

Then you know in so, coming to now the definition of the continuous casting. So, in turn continuous casting melt is transferred from the ladle via a tundish into the mold and further solidified as slabs blooms or billet us. So, what happens that in the case of continuous casting you have a ladle. So, this will be the ladle which will be getting the liquid steel.

Now, from this ladle the liquid metal will go into a vessel that is known as tundish this is tundish and in tundish has again different outlets. So, these are the outlets and from here they go into the mold and from this mold you know from here we have one attached you know this molded. So, this is coming completely liquid and here they will try and comment they start getting solidified. So, at one point of time they will come and get solidified here.

So, basically this length is the man known as also the metallurgical length. So, basically the liquid metal will be first received by ladle, ladle will be bringing that liquid metal and this ladle liquid metal is team to the tundish. Now, tundish basically is an open reservoir which has you know a large surface area. So, this you know tundish will take the liquid metal from ladle and then it will be from all it is outlet port you know there is mold attached and this mold basically is the copper mold in most of the cases and this is basically water cooled.

So, this is water cooled copper mold and you know then. So, this is known as the primary cooling zone of the continuous casting unit and then you have the cooling zones this here. So, you have the secondary cooling zone. So, this is not completely solidified some part solidifies it is further getting solidified by having the water sprays or. So, you have the secondary cooling zone. So, this is normally the schematic of a continuous casting process and you know in this way so, it will be solidified as the slabs blooms or billets. So, whatever you are getting the end product is either slab or it is bloom or the billet.

So, depending upon the different dimensions you define it as the you know billet if it is having a small cross square cross section, usually up to 150 mm square and up to 150 mm diameter round. So, if it is a square cross section of this dimension it is known as the billets. Blooms are the square or rectangular cross section which is greater than 150 mm square to as large as 800 mm by 400 mm usually with an aspect ratio of less than 2. So, it will be aspect ratio having less than 2, but it may go from 150 you know mm square to as long a large as 800 by 400.

And slabs are basically larger than blooms and they have normally the aspect ratio which is more than 2. So, they will have the you know that that dimension which is having more aspect ratio than even the blooms. So, this way these are the normally the end products of a continuous casting system now. So, what is happening, once ever since this continuous casting process has come into picture in the last 3 decades continuous casting has are all you can say in last 4 decades or.

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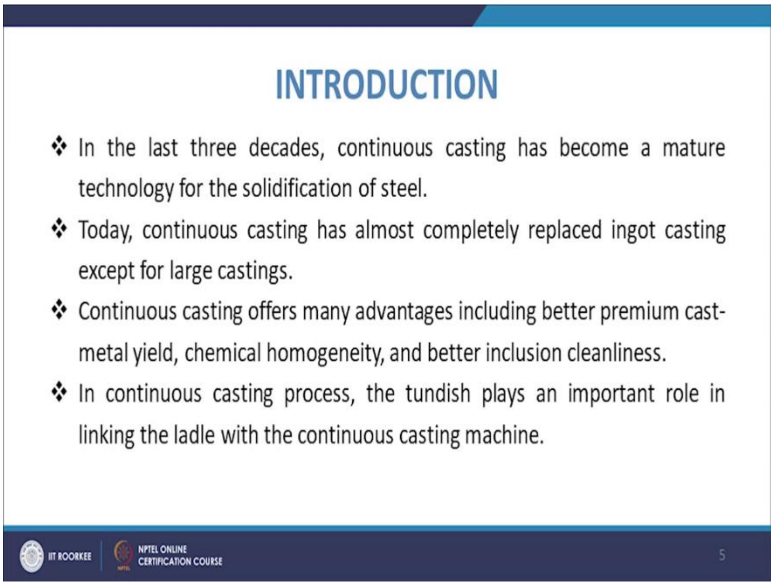

So, it has become a mature technology for the solidification of a steel and it has today almost completely replaced this ingot casting except for very large castings there we go for it, but otherwise we have completely replaced this process with continuous casting.

It offers many advantages including better premium cast metal yield, chemical homogeneity and better inclusion cleanliness. So, as far as the terminologies like the better premium cast metal yield. So, as you know that when we talk about the normal conventional casting you have a casting yield not very high because of the removal of gates and risers and other things, even if you take about the you know ingots also there also from the top certain portion has to be removed.

So, you know in most of the cases except the continuous casting you have the casting yield you cannot get as close to 100 percent whereas, if you talk about the continuous casting there is no you know wastage. So, the metal will is coming out and completely going out. So, there is no metal wastage so, you have a complete perfect yield you are getting.

Chemical homogeneity is there you know in this case the cooling rate is quite high and the solidification is complete in a very less time and you have many other you know technological advancement in continuous casting which is making the process even more chemically homogenous the composition more chemically homogeneous and also you have many ways to basically clean the steel by removing the inclusions and also do many things that we will see during the process of our study.

In continuous casting process the tundish plays an important role in linking the ladle with the continuous casting machine. So, as we have studied that the tundish is playing a very important role in the case of you know continuous casting because it is linking the ladle on one side and the caster on the other side or mold on the other side. So, that way tundish plays a very important role and that is why in this course we are going to have the discussion about the role of tundish and how you know the tundish flow or the phenomena which occurs inside the tundish is going to be important as far as the clean steelmaking is concerned.

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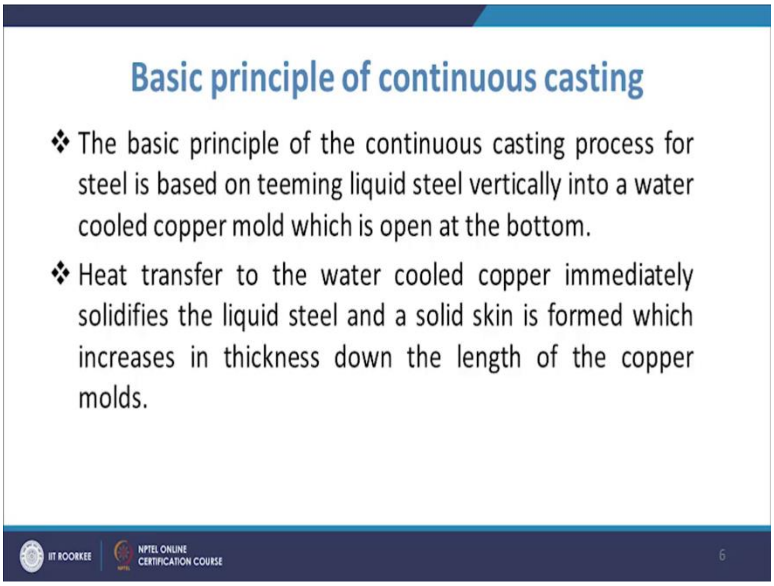

Basic principle of continuous casting is based on ah the teeming liquid steel vertically into a water cooled copper mold which is often which is open at the bottom. So, as we have discussed that in this case you have a mold and that mold is receiving the liquid metal from the top that is from the tundish at the top and the bottom is open. So, the metal which is coming downwards it is going to flow you know down itself, so you know and also the mold is made of copper.

So, heat transfer to the water cooled copper mold that is this is a mold basically immediately solidifies the you know liquid steel and solid skin is formed which increases in thickness down the length of the copper mold. So, we discussed in this case that the liquid from here we will come down and since this is a copper mold and it is externally cooled way by water.

So, immediately it starts solidifying you know from this point because the thermal superheat will be arrested and once you go you know below the liquidous temperature then the solidification will start. So, first of all the skin will be formed very small fine skin will be formed initially and that thickness of that cell will go on you know increasing further.

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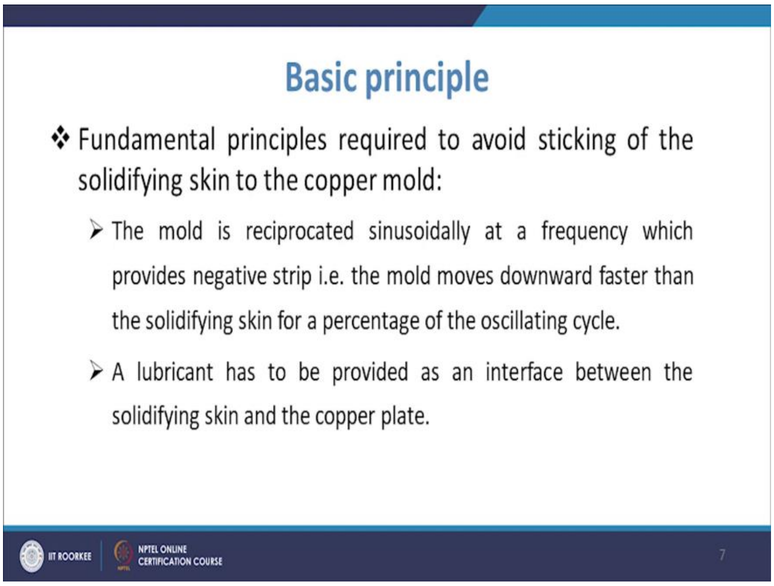

So, another principle which is required to avoid the sticking of the solidifying skin to the copper molds we discussed about this issue, that this is a challenge that how this solidifying skin and you know has to leave. So, the solidifying skin which is formed it must leave that and for that you know there are certain ways by which this is achieved one is that the mold is reciprocated since widely at a frequency which provides negative strips. So, basically it will be oscillating at a you know frequency which will be providing that negative strip that is mold will move downward faster than the solidifying skin for a percentage of the oscillating cycle.

So, in that case it will now we basically you know not be you know it will be do you have a negative strip that is known as. So, that helps avoiding the sticking of the solidifying skin to the copper mold and another thing what we do is that we also apply the lubricant at the interface between the solidifying skin and the mold that is made of copper. So, if there is a lubricating you know agent which is applied in that case it will not have you know the it will not have the chain tendency to get you know stuck or you know it will not be pasted to it so, it will go down.

So, these 2 are basically the basic principle which are you know used I mean which are which are required to be known to us that why there is no sticking of you know the solidifying skin to that copper mold. So, this is the basic principle of the continuous casting.

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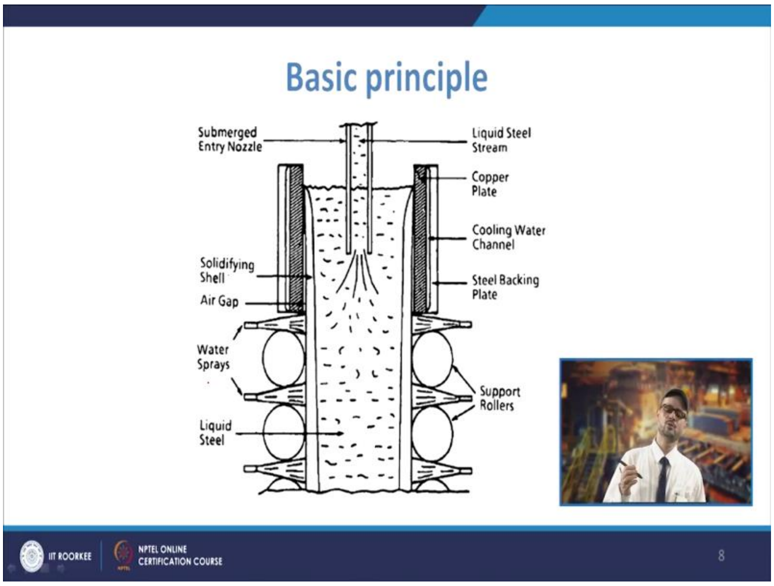

And if you look at this you know figure what you see as, we have seen that you have the liquid steel which is coming from here from the tundish now this is known as the submerged entry nozzle. So, this nozzle will be you know entered into the you know this mold.

Now, this mold is as we see that this is a copper plate mold and this is copper plate and this is what you see, this is the cooling water. So, this cooling water will be basically provided. So, that because coppers melting point is less than my 1100 degree centigrade pure copper is melts at 1083 degree centigrade and steels melting temperature is more than 1500 degree centigrade so, normally. So, in that case it has to be cooled externally with water. So, that is why you have the cooling water channel which is here and then it is supported by the steel backing plate because it leave it is a the strength and rigidity.

Then what you see that your liquid steel stream will be coming up it will be coming and then you have this is known as the primary cooling zone. So, in this case here there is development of solidifying cell up to this point. Now, it is further going down and then you know you have the rollers which will be supporting them. So it has to basically move downwards.

So, these support rollers are there and then also you have the spray you know use of spray water sprays are used basically to cool this you know strip. So, that basically this is your end product which is coming down. So, you are applying these water sprays from here and slowly your this thickness of the solidified cell will go on increasing as it is moving you know on the rollers and it is moving towards the exit.

So, this is basically the principle of the continuous casting and as it will move further then at some point of time you have to cut it. So, and that has to be ensured that where it is completely solidified so that length from there it will known as metallurgical length. So, after that you have a torch cutter and with the help of torch cutter you are going to further cut it so, of suitable length. So, that way you know you are getting the end products.

So, and also this mold this will be oscillated. So, as we have discussed that there will be oscillation of this and on the downward side it will be going at a faster rate. So, that there is a condition of negative strip that is maintained and also you before providing that you know lubrication what we do is, we provide a powder on that surface so, that is the flux powder is there.

So, this powder after melting it will go in between these you know here is the mold and this is the you know liquid steel. So, in between it will go and it will pass through it. So, it will ensure that there is no sticking of this liquid steel you know to the copper mold. So, to ensure that basically you are providing you know there are certain agents and you normally rapeseed oil has been seen to be used in earlier days and even now. So, that is that is not which avoids the you know sticking of that mold with the metal.

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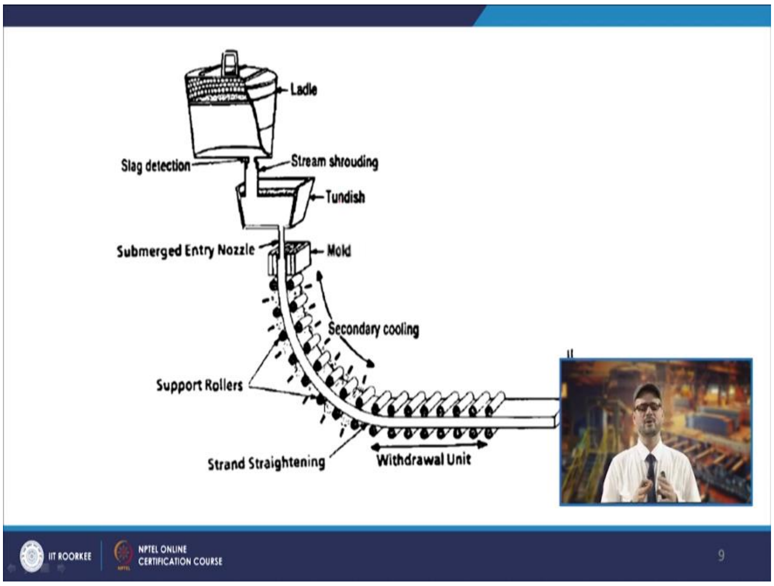

Now, if you look at the typical continuous casting unit as we were discussing about. So, you have the ladle and as you see this ladle will be making bringing the liquid metal then you have this is the tundish. So, you have shrouding is there and then it will bring this liquid steel to this tundish then from the tundish it will go to the mold. So, depending upon the number of outlets this tundish has you will have the different strand tundish. So, multi strand tundish or single strand tundish, 2 strand tundish or so, depending upon how many strands you have.

So, accordingly that we will have mold and this is the submerged entry nozzle. So, it will be going into the mold, then this will be solidifying inside the mold this and then normally you have a curved strand and you have the vertical type of continuous casting, you have horizontal type of continuous casting also, then what you do is you provide a you know bend. So, this will be a sub in the form of this, support rollers so this solidified you know cell along with the liquid metal will move.

So, the external part is still solidified an internal part is still liquid. So, that will be moving on to this with the help of these rollers the rollers will be moving. So, it will be moving in this direction and then it will once it comes here you have a bent, because ultimately you need if you go for the completely vertical size you require very large vertical space which is many a times troublesome on many grounds like there will be a space requirement problem and also handling issues and all that. So, what you do is, you take vertically the liquid metal into the mold and after that you are a taking a bringing that into a horizontal form. So, for that you are providing this you know bend and then once it is bend so, you have to make it straight and so, for that you further straighten it with the help of these rollers.

So, you have strand straightening going on and after that once. So, that is that is completely solidified and completely straightened then with the help of flame cut off you are you know cutting. So, whatever length you require you can have it and then you can cut and then further you can send it for the further use.

So, this is the normally the continuous casting you know a schematic you know and it involves all the you know processes which take place. So, what we have seen in this class about in this lecture about the usefulness of continuous casting process it is traits. We will be talking more about the tundish and other allied devices in the process of continuous casting.

Thank you very much.