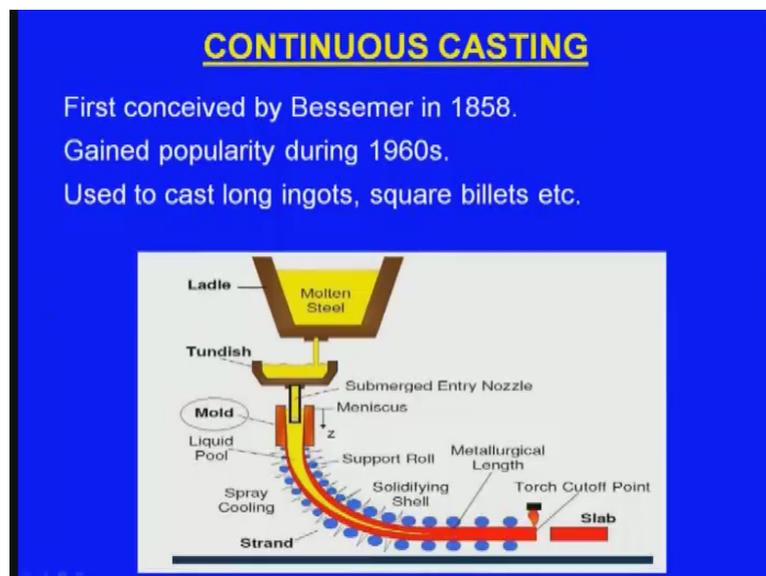


Metal Casting
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Module – 05
Permanent Mould And Special Casting Processes
Lecture - 05
Continuous Casting Process

Good morning friends, in this lecture let us learn about continuous casting process. This continuous casting process was first conceived by Bessemer in the year 1858, later it gained popularity during 1960s.

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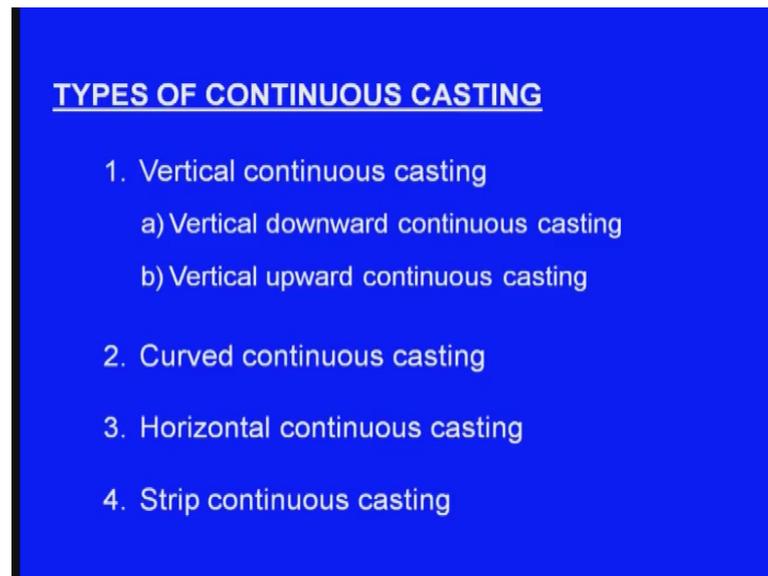


And it is used to cast long ingots square billets and many more what say complex sectioned components and this is a simple principle of the continuous casting and here is the ladle in which there will be molten steel or some other molten metal will be there and here there is a tundish means a reservoir of the molten metal, below the tundish there is a mold this is the water cooled mold will be there. So, from the molten what say ladle the molten metal will be poured into the tundish and from the tundish and it will be passing through the mold where there will be cooling system and it will be cooled down.

So, slowly the solidification is again increasing you can see here. So, slowly there will be it will be moving and there will be rollers will be there and these rollers will be rotating and you can see here by the time it comes here, it is totally solidified then it will be

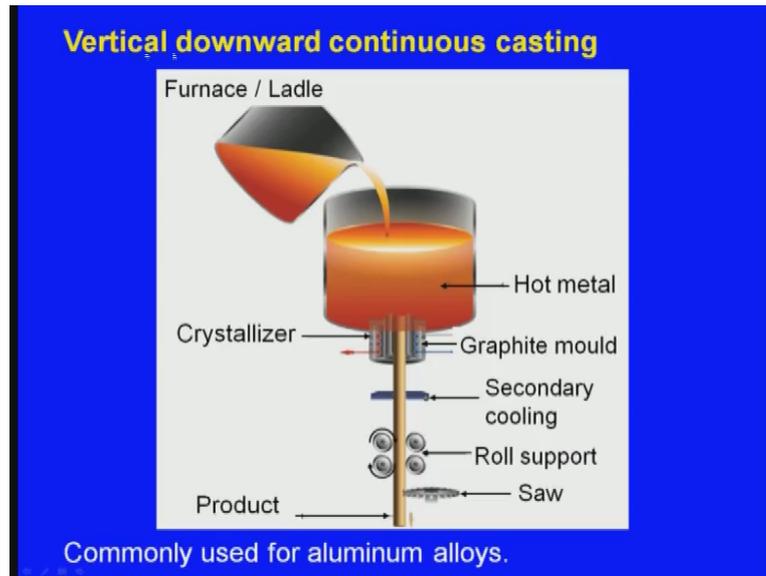
further moving and here it will be cut using some torch or any staksaw it will be cut and here this is the finished slab. So, it can be a cylindrical slab, square slab, hexagonal slab or any other what say the section. So, this the a principle of continuous casting. So, before going a; what say further let us see the classification types of the continuous casting process.

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Broadly they can be classified into four types, one is the vertical continuous casting second one curved continuous casting, third one horizontal continuous casting and the fourth one strip continuous casting and the first one the vertical continuous casting is sub classified as vertical downwards continuous casting, and the other one is the vertical upward continuous casting. Now we will see all this one by one first we will see the vertical continuous casting under that let us see the vertical downwards continuous casting.

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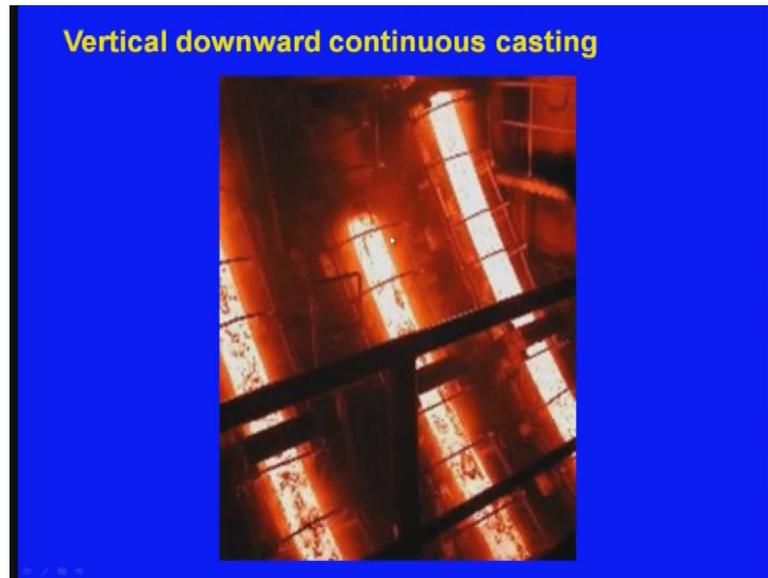


So, this is the vertical downwards continuous casting means the solidified billet or the solidified bar will be travelling towards the bottom towards downwards. So, that is the vertical downwards continuous casting.

So, here we can see this is the furnace in which the molten metal is there and this is the tundish means a reservoir a local reservoir which accommodates the molten metal. Now below the tundish there is a graphite mould is there, you see this is the graphite mould. Now the molten metal from the ladle is poured into the tundish and from the tundish the molten metal will be flowing through the graphite mould as it is flowing there is a cooling system is there and also there is a crystallizer because of that it solidifies as it is going out of the graphite mould, and by the time here it comes to the a place called secondary cooling and here it will be further cooled. Now further it still comes down and here there are roll supports are there. So, this will be rotating like this and another roll will be rotating like this. So, because of that the solidified bar will be coming down.

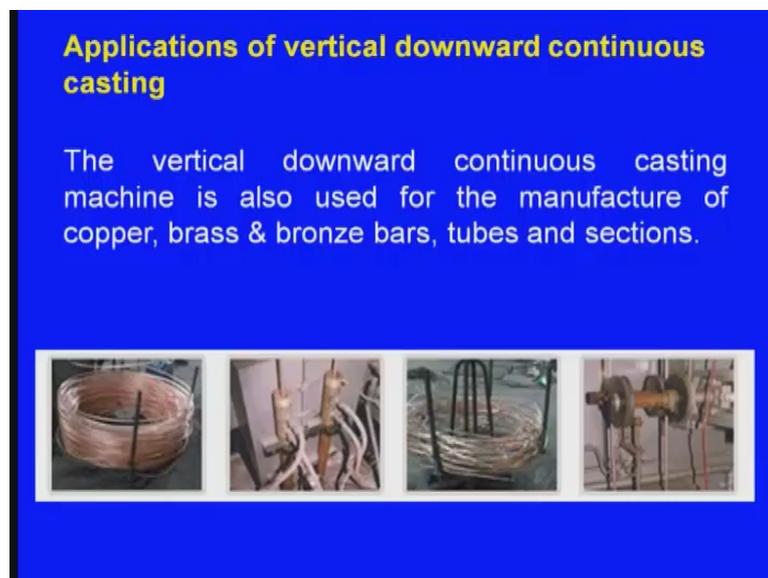
So, after it is completely solidified, you see here here there is a saw. So, it cuts periodically. So, of the solidified bar and the cut bar is taken and it is sent for the further processing. So, this the a principle of vertical downwards casting continuous casting.

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And here we can see it goes like this, now what the applications of vertical downward continuous casting.

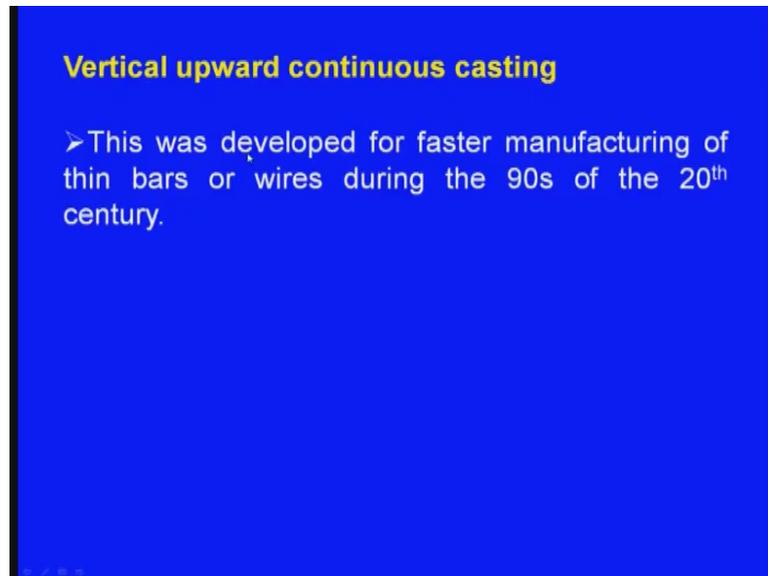
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The vertical downward continuous casting machine is also used for manufacture of copper brass and bronze bars tubes and sections. So, this are all the different components produced by vertical downward continuous casting. Second one under the vertical continuous casting is the vertical upward continuous casting, in the case of the vertical downward continuous casting the solidified bar is coming downwards, but in the case of

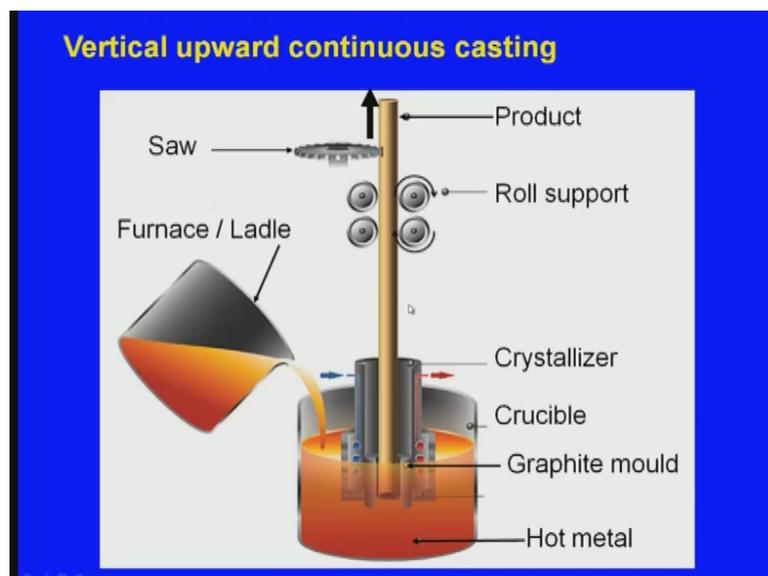
the vertical upward continuous casting, the solidified bar goes upwards in the opposite direction.

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This was developed for faster manufacturing of thin bars or wires during the nineties of the twentieth century.

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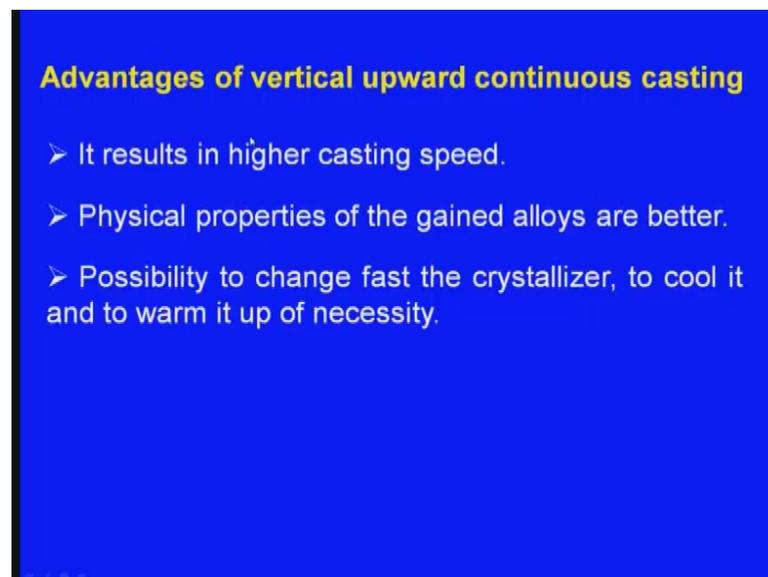


This is the what say schematic of the vertical upward continuous casting, and here this is the tundish means a local reservoir of the molten metal and this is the ladle. Now we

poured the molten metal from the ladle into the tundish. Now here is a system that after solidification it will be pushed to pass through the graphite mould you see here is a graphite mould. So, it is pushed to pass through the graphite mould then what will happen it will be coming upwards. Now here there is a crystallizer and also a cooling system will be there, because of that the solidified bar will be moving upwards slowly it will be moving upwards. Yes once it comes to this section it is totally solidified then there is a roller support is there this rollers will be rotating and there will be further pushing the solidified upwards and here there is a saw.

So, this are cuts the solidified bar periodically or at the desired location.

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What are the advantages of upward what say vertical upward continuous casting it results in higher casting speed physical properties of the gained alloys are better in this case. Next one possibility to change fast the crystallizer to cool it and to warm it up of the necessity.

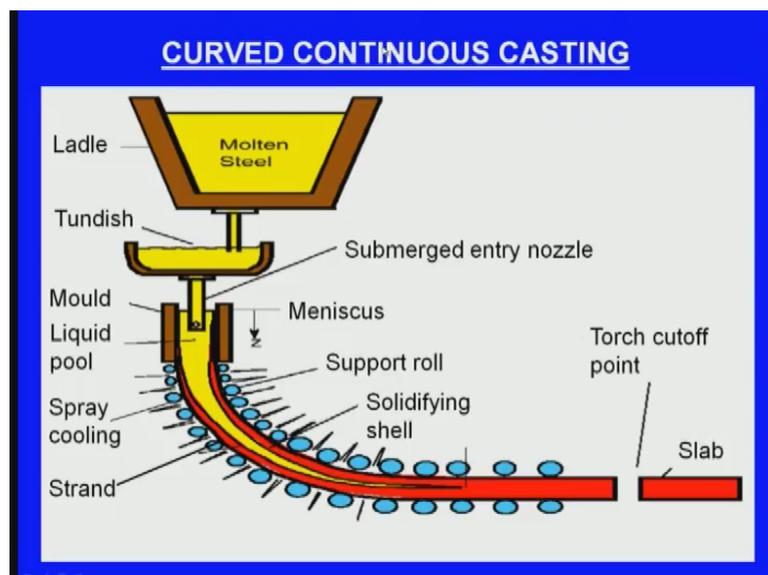
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Applications of vertical upward continuous casting

- This method is being basically used for manufacturing products of 8-30 mm diameter.
- Vertical upward casting is applied for casting of bronze, copper, nickel alloys.

Applications of vertical upward continuous casting, this method is being the basically used for manufacturing products of 8 to 30 millimeters diameter means for smaller diameter components or the box this method can be successfully used. Vertical upward casting is applied for casting of bronze copper and also nickel alloys. Next one let us see the curved continuous casting. So, we have completed the first category now we will see the curved continuous casting.

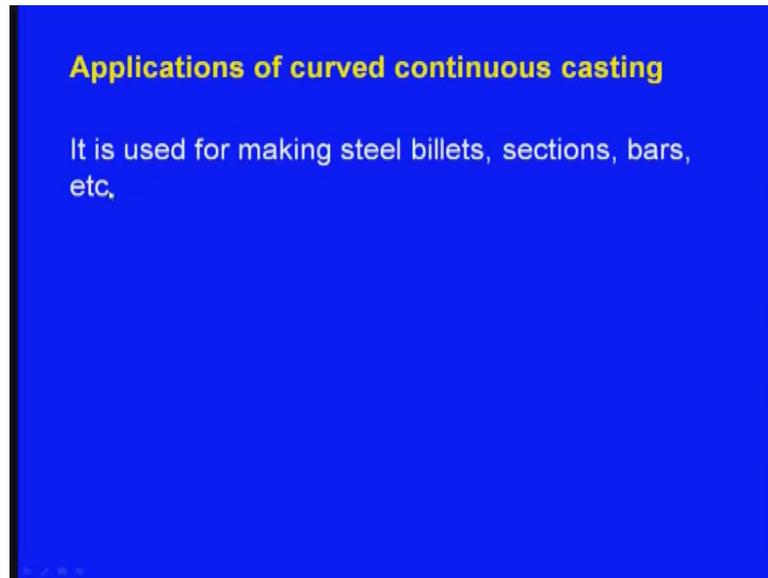
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The curved continuous casting the schematic looks like this, similar to the vertical downwards casting, but there is a difference. In the case of the vertical downwards casting the bar only comes downwards, but it does not bend it does not any curve, but here yes if the molten metal from the what say tundish it comes downwards to some extent, then it will take a curve and it becomes horizontal that is the curved continuous casting and the principle is almost to similar to the previous ones and here there is a ladle which accommodates the molten steel, this curved continuous what say casting process is from mainly used for making steel billets. So, here we can see this is the molten steel is here in the ladle, from the ladle it comes to the tundish; tundish means the local reservoir.

Now, here there is the mould So, it passes through the mould around the mould there will be cooling system will be there. So, as the molten metal passing through the mould it will be undergoing solidification, solidification commences which is solidification is gradually increasing here it here it as started and solidification is gradually increasing by the time it comes to this point, the solidification is complete. Now here there is you can see at this is a mould and here there is a spray cooling, cooling system will be there by means of a spray. Now here there will be support roller will be there. So, this rollers will be rotating; as the rotating the solidified bar will be taking a curve and slowly it takes a horizontal direction and by the time it comes here it is totally solidified, now some where here it will be cut using some torch or a saw. So, likewise as the what say solidified bar is coming out it will be periodically cut or it will be cut at the desired position. So, this is the a principle of the curved continues casting.

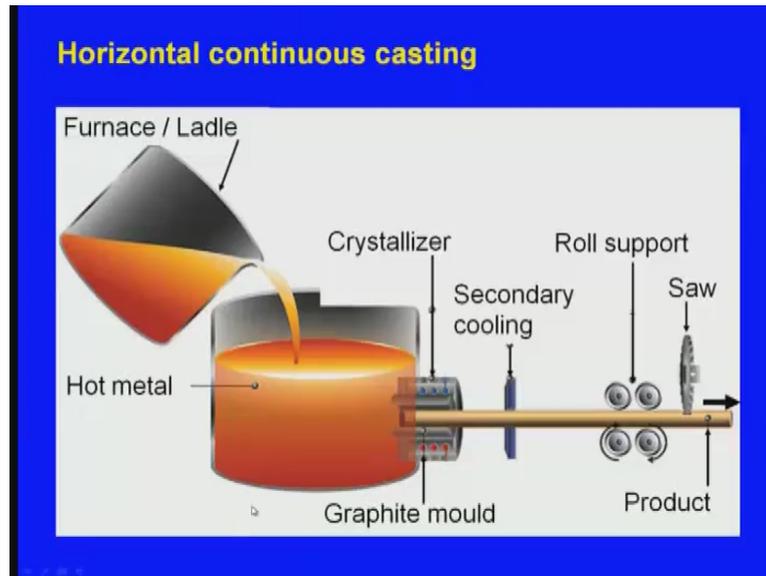
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Applications of curved continuous casting; it is used for making steel billets sections bars and so on.

Next one let us see the horizontal continuous casting what is the principle here? Yes in the previous case in the case of the vertical downward continuous casting the solidified bar was coming downwards, and in the case of the vertical upwards continuous casting the solidified bar was going upwards in the case of the curved continuous casting the solidified bar was coming downwards and it is taking a curve and it becomes horizontal and here the solidified bar Right from the beginning will be moving horizontal, that is principle here.

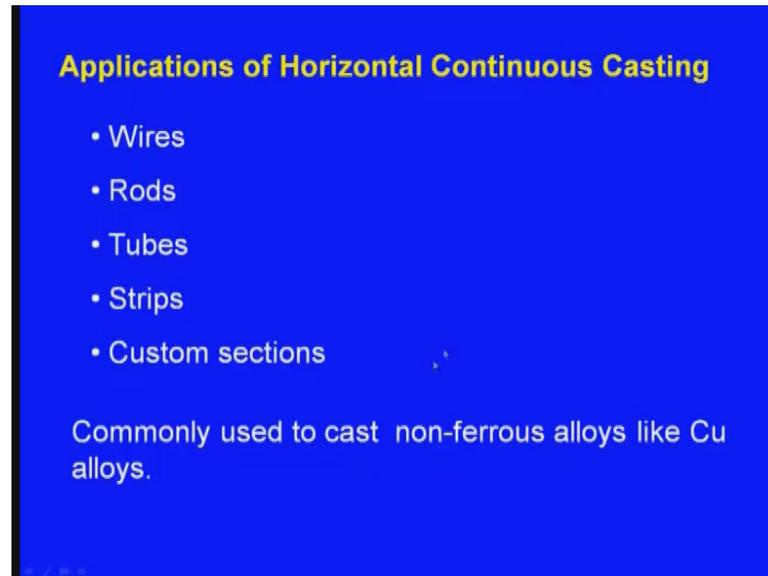
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Now this is the furnaces this is the ladle from the ladle it will be flowing into the tundish; tundish means the local reservoir and here we can see here is the graphite mould and the graphite mould will have a possess may be a circular possess or a square possess or a hexagonal possess depending up on the requirement and here there is a crystallizer means a which cools down and it what say enables formations of the crystallization, next one here is the secondary cooling yes as the molten metal is transferred from the furnaces to the hot what say tundish and it will be flowing through the graphite mould. As it is flowing out of the graphite mould because of the crystallizer crystallization takes places and its solidification starts and by the it comes somewhere here it is totally solidified and here is the secondary cooling.

Once it passes the secondary cooling, it is totally solidified and here there are roller supports are there, these roller supports will be pulling the solidified bar away from the mould and some where here there is a saw. So, this saw again it will be cutting the solidified bar at the equal what say intervals or at the desired location. So, this is the principle of the horizontal continuous casting what are the applications of horizontal continuous casting.

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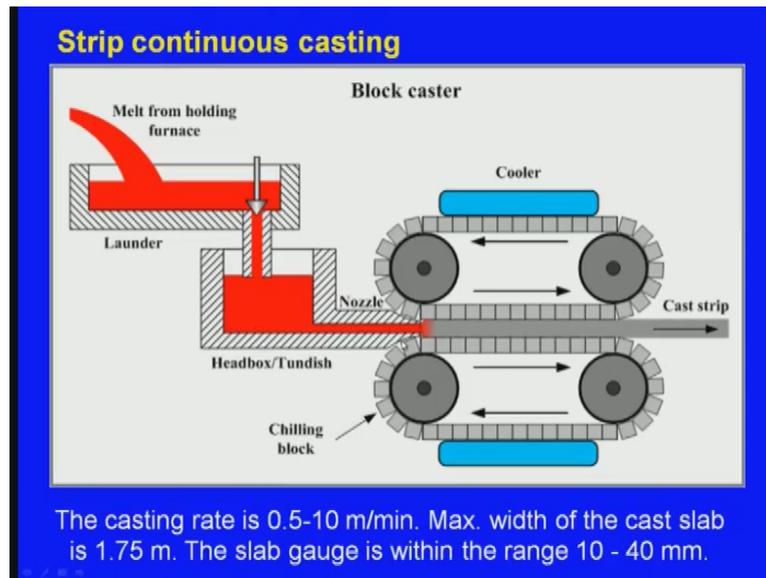
Making of thin wires, making of rods, making of tubes, making of strips and what say custom sections and commonly used to cast non ferrous alloys like copper alloys.

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So, this of the what say typical components produced by the horizontal continuous casting finally, let us see the strip continuous casting. So, this is the last one.

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Now, this is the what say schematic diagram of the strip continuous casting, and here you can see here this is the molten metal from the furnace from that ladle it is being transferred. So, this is the tundish again a local reservoir of the molten metal and here we can see the what this is the what say place where the molten metal will be passing through rollers you can see here, this is one what say a roller or the cast roller and here you can see one more roller is there. So, this will be moving. So, this cooler this what say roller will be moving in this direction and this will be moving in this direction, now the molten metal will be passing through the gap between these through rollers and there will be a cooling system will be there you can see here there is a cooling system between this two rollers. So, as the molten metal is flowing through this through this two what say strips two rollers by the time it comes out it will be solidified and here we can see this is the cast strip a thin cast strip is coming out.

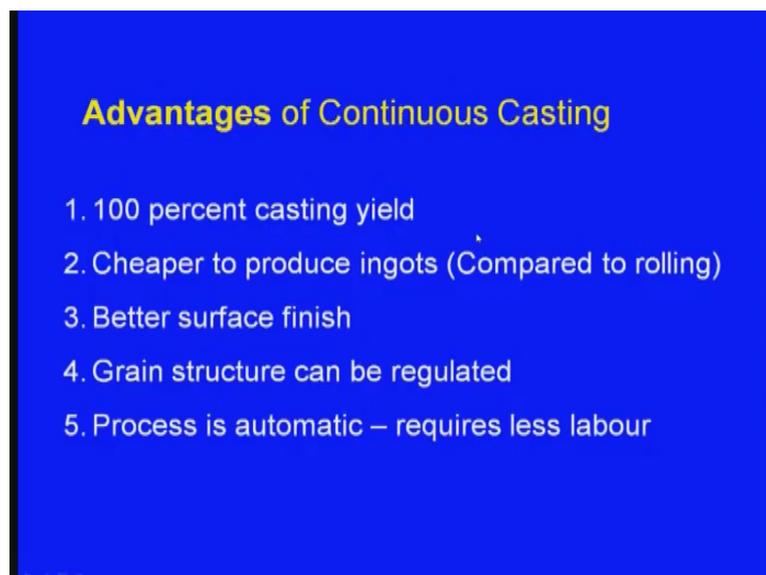
So, this is the strip continuous casting we are not producing any bars or rods here, but thin and wide strips are produced in this process. Now the casting rate is you can here 0.5 to 10 meters per minute, maximum width of the cast slab is 1.175 meters, slab up to the width of 1.175 meters can be produced, the slab gauge is within the range of 10 to 40 millimeters. So, this is the thickness of the strip 10 to 40 m m applications of strip continuous casting.

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It is used to produce bars and tubes are maximum diameter is 40 centimeters, next one it is also used to produce wires and their maximum diameter is say 16 to 25 millimeters and what are the alloys covered under this process? Copper brass bronze nickel silver cooper nickel and precious metals can be what say cast using this strip continuous casting process.

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Let us see the advantages of the continuous casting broadly, whether it is the downwards casting or the upwards casting, where it is the curved continuous casting or the horizontal

continuous casting what are the advantages in general n? It is the it gives us 100 percent casting yield what is this casting yield let us the principle.

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$$\text{Casting yield} = \frac{\text{Wt. of the casting} * 100}{\text{Wt. of poured metal}}$$

Casting yield is defined as the weight of the casting divided by weight of the poured metal multiplied by 100. So, this is the definition for the casting yield, in any of the casting process whether it is the sand casting process or the investment casting process or any other casting process the weight of the poured metal is always greater than weight of the casting that is how the casting is always less than 100 percent, but in this case in the case of the continuous casting we are not losing anything, whatever we pouring we are getting as a strip or as a bar or as a rod.

So, here we are getting 100 percent casting yield, second advantage is cheaper to produce ingots compared to rolling. Ingots can be produced by rolling also, but if we produce them by rolling the cast is more, but if you produce them by continuous casting of course, the initially establishment cast may be more, but the running will be lesser compared to the rolling next one in this case using continuous casting we get good surface finish or the better surface finish, next advantage is grain structure can regulated the process is automatic it requires less labour. So, these are the advantages of the continuous casting process these are the applications of continuous casting in general.

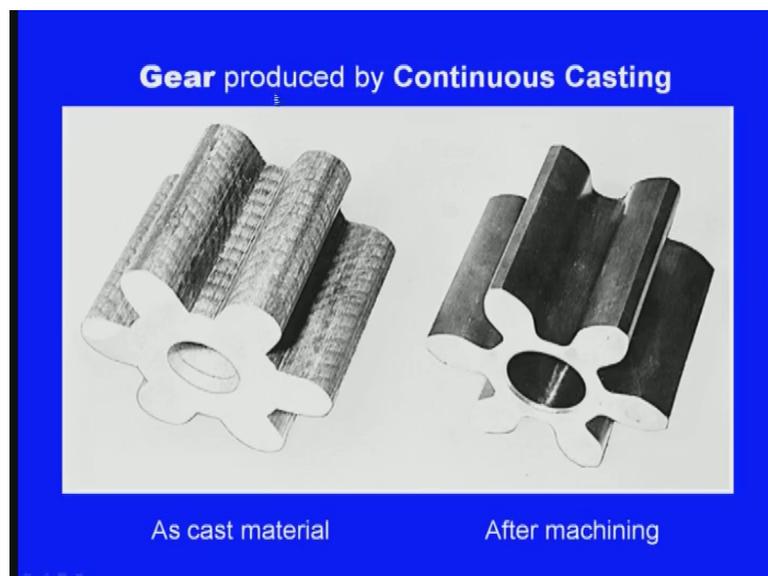
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Long billets of any cross section can be obtained where it is the round square hexagonal gear toothed or any cross section can be obtained or that to long billets can be obtained using the continuous casting process. Solid and hollow ingots also can be produced not only solid, but also hollow ingots can be produced.

Next one bushing and pump gears can be produced using continuous casting process, next one production of copper bars or the wire using continuous casting is very easy and it is economical.

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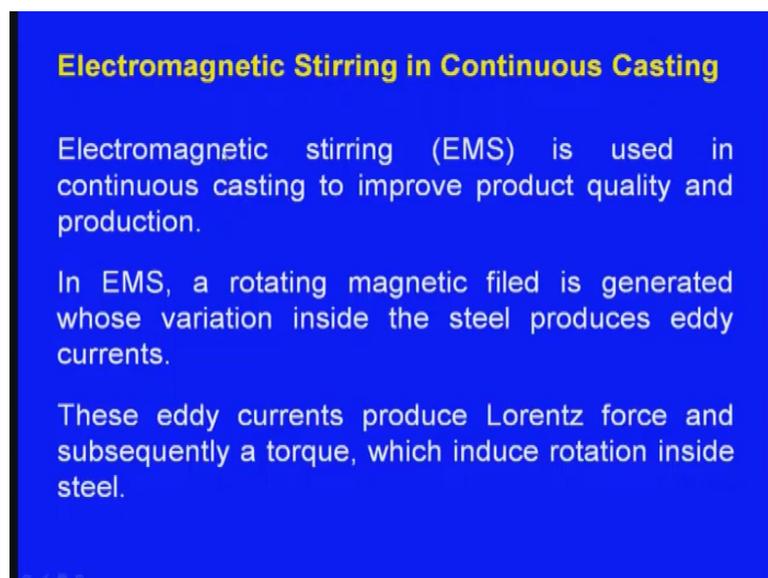
So, these are the what say a typical components produced by continuous casting. So, this is the what say gear blank produced by continuous casting, this is as cast material without any machining the what say bar the cast bar of the it looks like this after machining yes it looks like this. So, this is the what say gear blank of course, this can be get into several slices depending upon the requirement.

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Next one let us see the advances in continuous casting process.

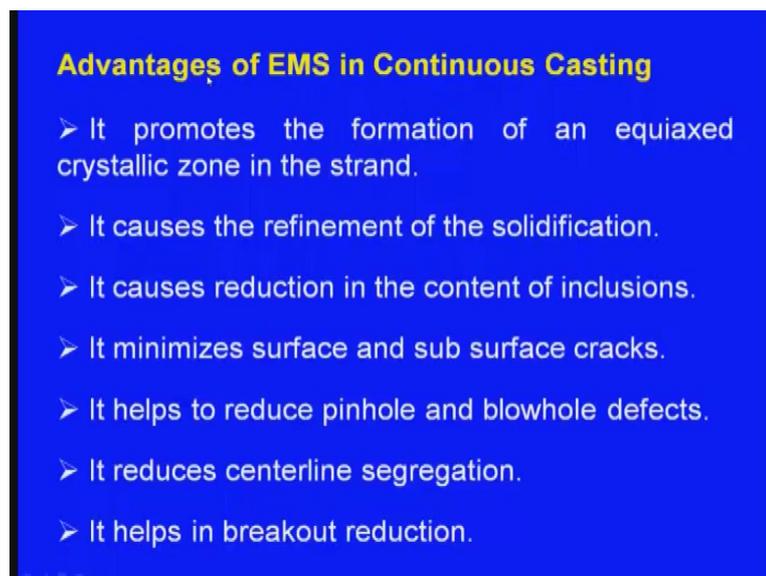
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The most important advance is the electromagnetic stirring it is also known as EMS. So, this electromagnetic stirring or EMS is used in the continuous casting to improve product quality and production. How in EMS a rotating magnetic field is generated whose variation inside the steel produces eddy currents.

We apply what is called a rotating magnetic field; because of that eddy current is produced inside the molten metal. Now these eddy currents produce Lorentz force and subsequently a torque which induces rotation inside the molten metal or inside the steel. So, because we are producing the magnetic field what is called eddy currents are produced inside because of these eddy currents Lorentz force is produced and because of that there will be rotation inside the molten metal. So, this causes the what is called green improvement what are the advantages of the electromagnetic stirring in continuous casting.

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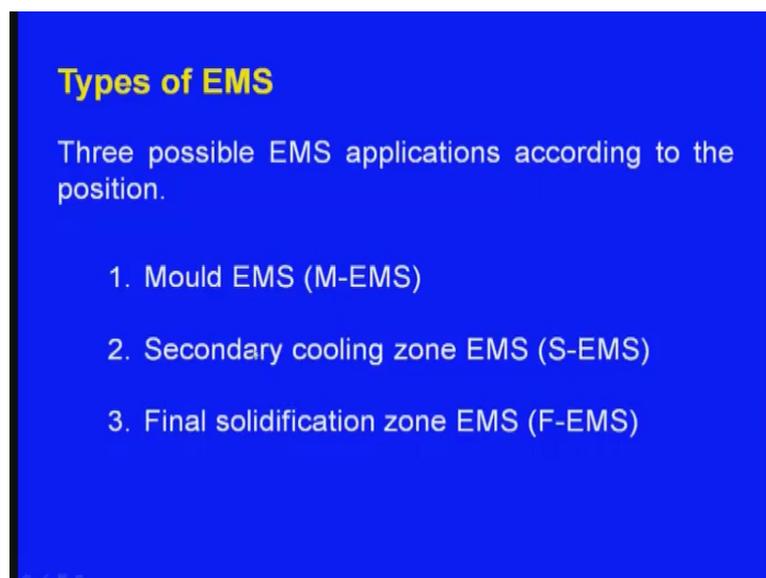


It promotes the formation of an equiaxed crystalline zone in the strand, we get the it is possible that there may be equiaxed grains or the clamorous grains or the dendritic what is called structure may be there, but equiaxed crystalline zone is always favorable. Equiaxed grains are always a better compared to any other grains. So, when we give the EMS we get the equiaxed grains, next one this EMS causes refinement of the solidification grain refinement can be achieved. So, because of the grain refinement we get the better mechanical properties.

Next one it causes reduction in the content of inclusions. If there are any unwanted inclusions will be there they will be reduced because of the EMS next one EMS minimizes surface and sub surface cracks. So, once, we apply the EMS grains will be removed larger grains will be broken into smaller grains. So, because of that surface and sub surface cracks will be minimized, next one it helps to reduce pinhole and blowhole defects. So, this pinhole and blowhole defects arise due to the presence of the dissolved gases. So, when we cause this what say this EMS what happens inside the metal will be rotated. So, because of that if there are there is any unwanted gas or the dissolve gas it will be coming out. Next advantage is the it reduces centerline segregation, next one it helps in break out reduction what is the problem? Sometimes when the solidified bar is coming out or as it is going away from the mould due to the rotation of the rollers somewhere it breaks.

Wherever it breaks that is a waste again we have to cut it and we have to damp it in the what say furnace. Now because of this EMS application this breakout will be reduced. So, that is another important advantage of the electromagnetic stirring in the continuous casting. Now we have seen the importance and applications advantages of the electromagnetic stirring in continuous casting, now there are three types of the EMS applications are there.

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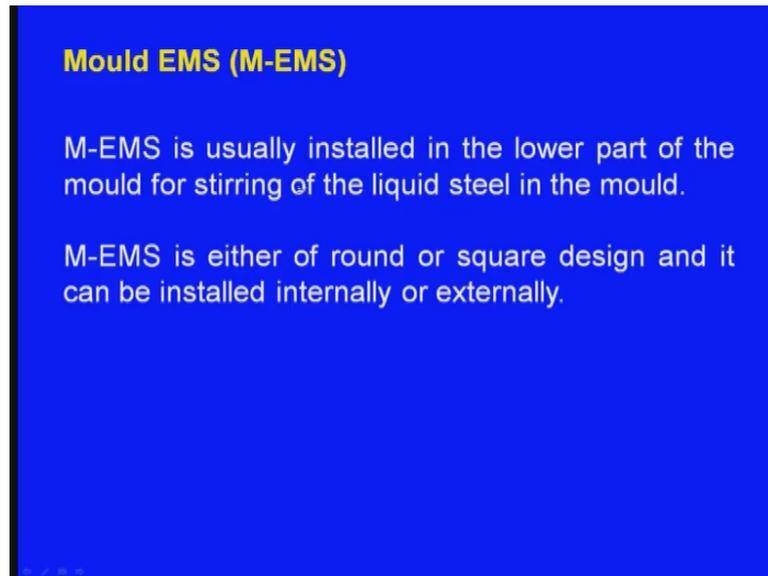
Types of EMS

Three possible EMS applications according to the position.

1. Mould EMS (M-EMS)
2. Secondary cooling zone EMS (S-EMS)
3. Final solidification zone EMS (F-EMS)

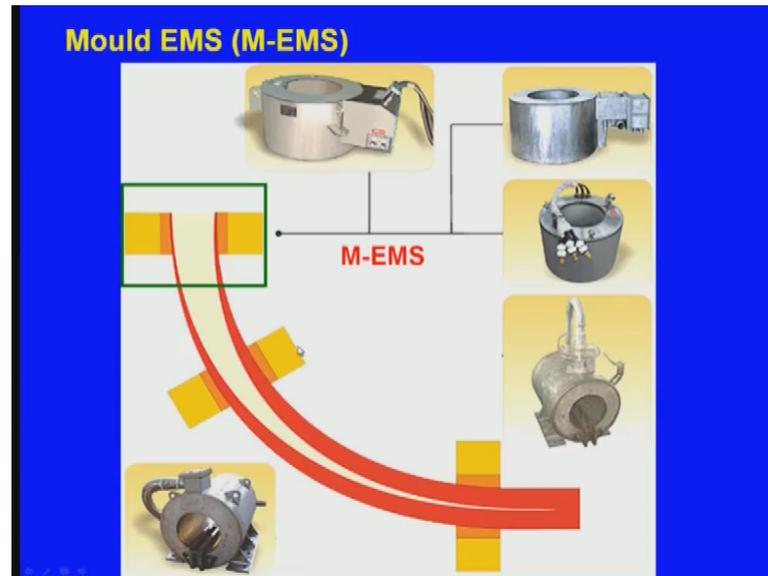
Three possible EMS applications according to the position are one is the mould EMS mould electromagnetic stirring, it is also known as M-EMS. Second one EMS appeared at the secondary cooling zone. So, this is known as the secondary cooling zone EMS or simply S-EMS. Next one final solidification zone EMS or F-EMS now we will see this one by one first we will see the mould EMS or M-EMS.

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M EMS is usually installed in the lower part of the mould for stirring of the liquid steel in the mould. M-EMS is either of round or square design and it can be installed internally or externally let us see how it is.

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Yes this is the continuous casting what say process it is going on. So, here is the mould and through the mould the liquid metal is coming and gradually it is solidifying yes by the time it comes here it is totally solidified. Now this M-EMS is applied here around the mould see here. So, this is the mould this is the mould around the mould it is applied. So, this is known as the because we are applying around the mould it is known as the mould EMS or M-EMS.

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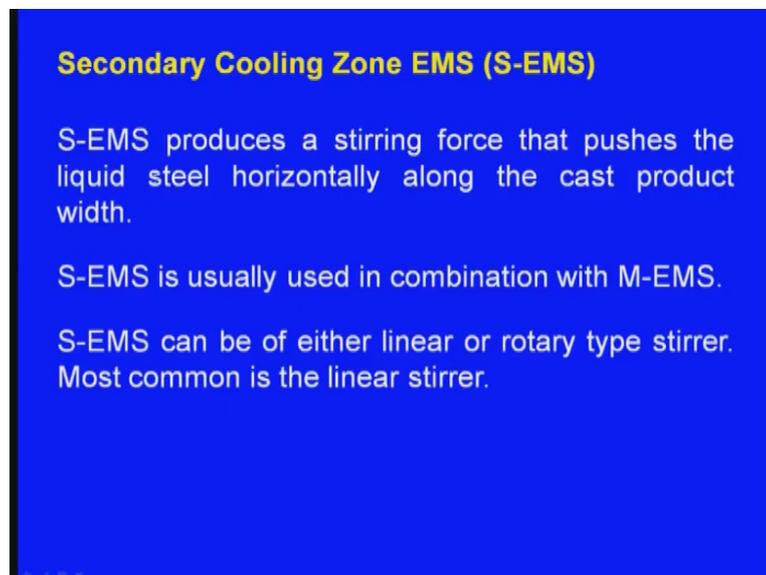
Advantages of Mould EMS (M-EMS)

- The application of M-EMS results into reduction of pinholes, centre porosity and segregation in the cast product.
- It improves the solidification structure, reduces the surface roughness and increases the heat delivery rate.

Now, the application what are the advantages of mould EMS. The application of M-EMS results into reduction of pinholes centre porosity and segregation in the cast product if there are any pinhole due to the presence of gases they will be minimized. Next one it proves the solidification structure reduces the surface roughness and increases the heat delivery rate.

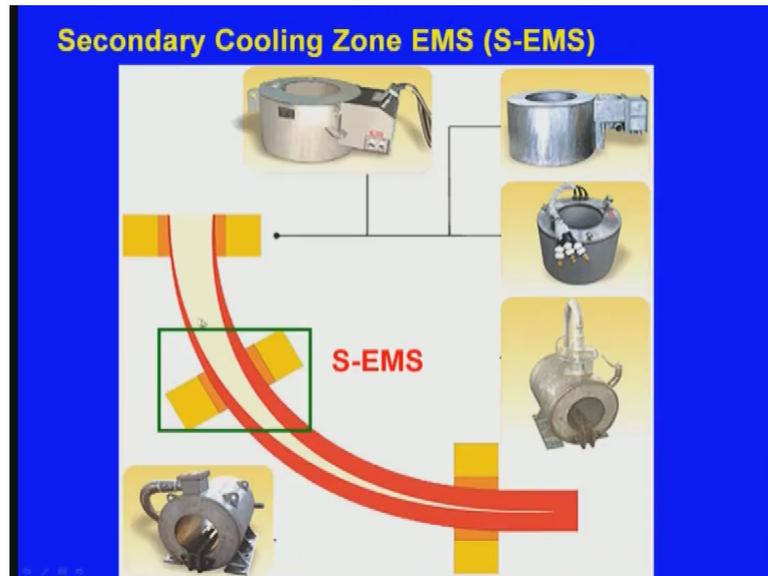
So, these are the advantages of the mould electromagnetic stirring. Now let us see the second type of EMS secondary cooling zone EMS or it is also known as S-EMS what is this again let us see.

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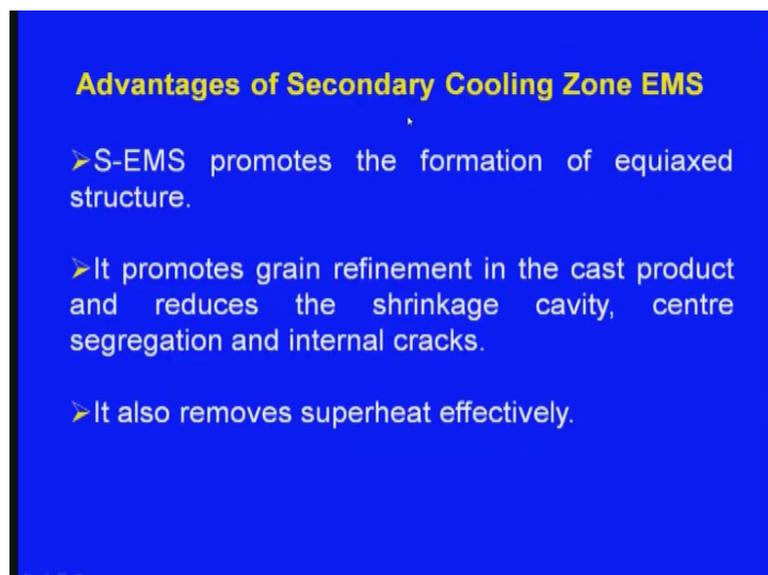
S EMS produces a stirring force that pushes the liquid steel horizontally along the cast product width, we can see here it pushes the liquid steel horizontally along the cast product width. Next one S-EMS is usually used in combination with M-EMS means prior to applying S-EMS we should also use M-EMS means the electromagnetic stirring around the mould. S-EMS can be of either linear or rotary type stirrer most common is the linear stirrer.

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Yes it is where S-EMS is applied. So, this is the way waste where we apply the M-EMS then the what say solidified bar is coming like this and here is the secondary cooling zone. So, near the secondary cooling zone we place the S-EMS setup. As the molten metal solidified metal is passing through S-EMS we get the required what say properties now these are the advantages of secondary cooling zone EMS.

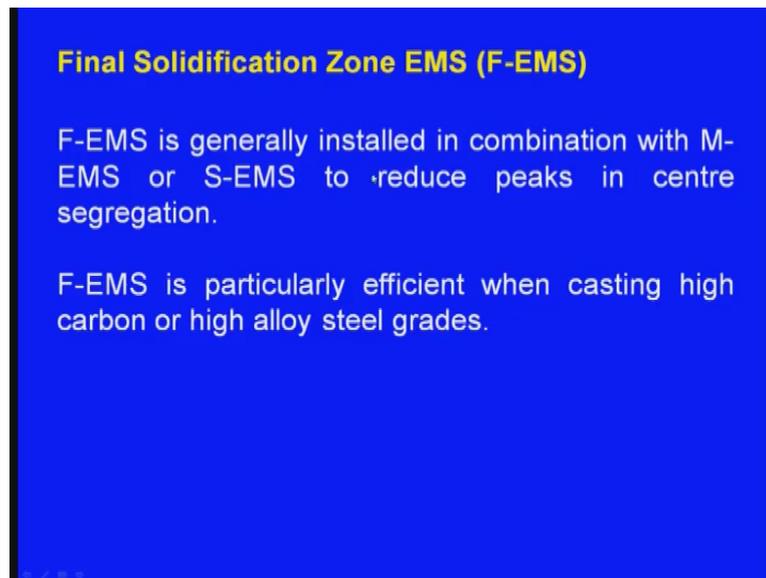
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S EMS promotes the formation of equiaxed structure, again it very important and most required property equiaxed grains will be getting. Next one it promotes grain refinement

in the cast product and reduces the shrinkage cavity centre segregation and internal cracks. Next one it also removes super heat effectively once we remove the super heat effectively the solidification becomes faster. So, we have completed the first two now finally, let us see the third one that is the final solidification zone EMS F-EMS.

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F-EMS is generally installed in combination with M-EMS or S-EMS to reduce peaks in centre what say segregation. So, if we want to apply F-EMS prior to that we should have used either M-EMS or S-EMS.

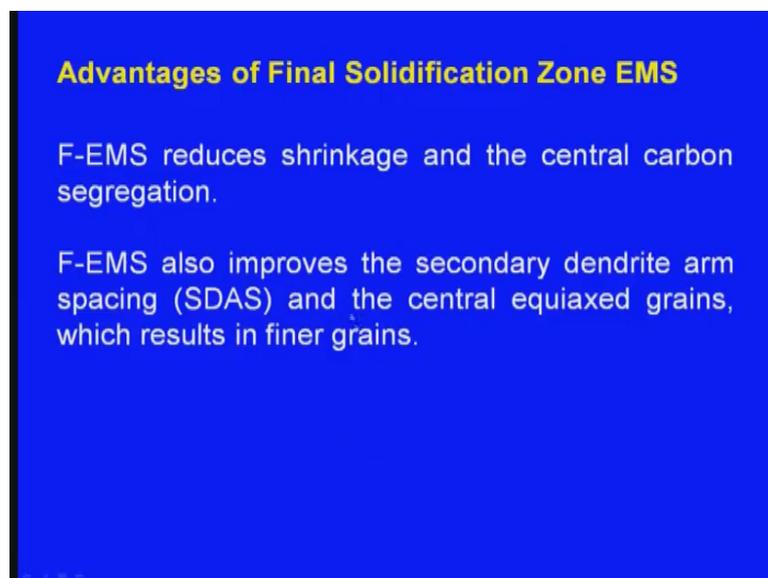
F EMS is particularly efficient when casting high carbon or high alloy steel grades yes again here.

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This is the place where we apply the F-EMS means, after finite solidification he you see here. So, here we apply the F-EMS. So, this the F-EMS setup what are the advantages of final solidification zone EMS.

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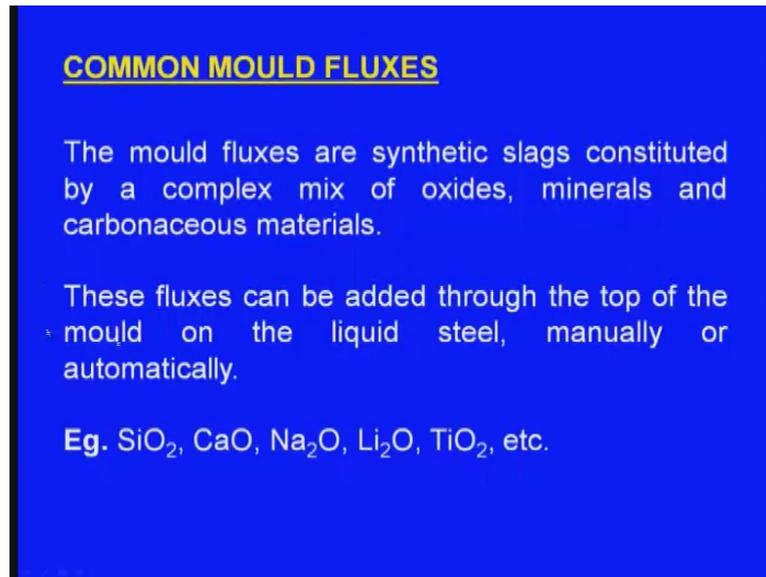


F EMS reduces shrinkage and the centre central carbon segregation, next one F-EMS also improves the secondary dendrite arm spacing and the central equiaxed grains which results in finer grains. Now with this we are we have completed the types of the what say

EMS what say EMS process, we have seen three types of the EMS s that can be applied in the continuous casting process

Next let us see the common mould fluxes used in the what say continuous casting process.

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COMMON MOULD FLUXES

The mould fluxes are synthetic slags constituted by a complex mix of oxides, minerals and carbonaceous materials.

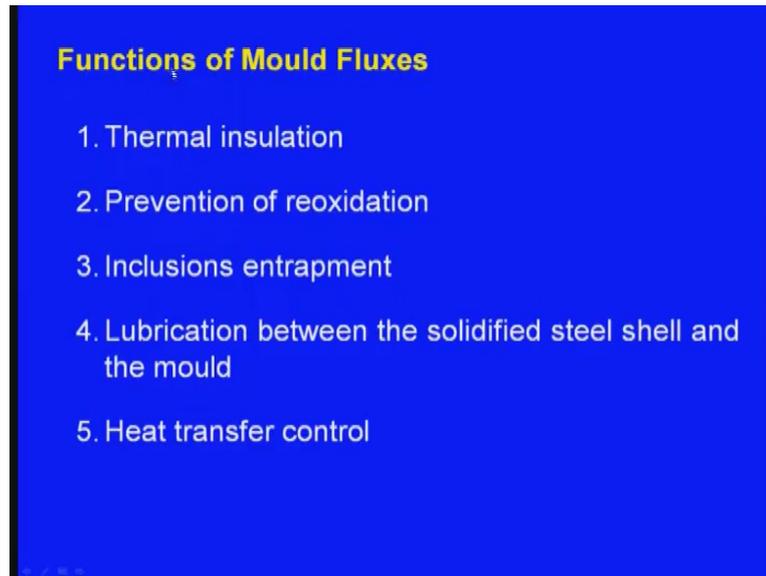
These fluxes can be added through the top of the mould on the liquid steel, manually or automatically.

Eg. SiO_2 , CaO , Na_2O , Li_2O , TiO_2 , etc.

The mould fluxes are synthetic slags constituted by a complex mix of oxides minerals and carbonaceous materials. So, these of the ingredients of the mould fluxes, we use the mould fluxes in the continuous casting. So, how these are added? These fluxes can be added through the top of the mould on the liquid steel manually or automatically yes in the tundish we pour the molten metal from the furnace or from the ladle, just above the tundish we will place this fluxes manually or automatically what are their common what say fluxes? Yes it can be silicon dioxide calcium oxide sodium oxide lithium oxide and titanium dioxide.

So, any of this mix a mix of any of this can be used as the mould fluxes. Now the next question is why we should add the mould fluxes what are the functions of this mould fluxes.

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So, these are the functions of the mould fluxes, one is the thermal insulation that offers us thermal insulation because heat is not wasted. Sometimes we expect to be in the molten state for some time, but it solidifies, so heat is going out, but these fluxes act as thermal insulators. Next is prevention of reoxidation, as there may be oxidation, this will be prevented. Next is the entrapment of inclusions, which will be trapped because of the fluxes.

Next, one of the most important functions is that they act as a lubricant between the solidified shell and the mould. If this lubrication is not present, the solidified shell will stick to the mould and break as it is pushed downwards. Fortunately, these mould fluxes act as lubricants. Next, they also control the heat transfer rate so that the shell will solidify at the required place and at the required time.

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Next one let us see the continuous casting defects. So, so far we have seen the different types of the casting process we have seen and the different types of the what say EMS applications we have seen and moulds fluxes we have seen now finally, the continuous casting defects what are the continuous casting defects? We have seen the advantages and applications of the continuous casting, but at times we also get the defects, and if we do not know how to control these defects most of the labour and time that we are investing will go wasted. So, you have if you want to prevent this loss we must be aware what are the defects that are likely to arise and what are the factors that are influencing these defects we need to learn, now let us learn about the defects.

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CONTINUOUS CASTING DEFECTS

1. Sticking of fluxes
2. Slag entrapment
3. Longitudinal cracks
4. Transverse cracks
5. Star cracks
6. Longitudinal depressions
7. Transverse depressions
8. Blowholes
9. Interruption in the physical continuity
10. Shrinkage cavity

So, these are the what say common continuous casting defects, one is the sticking of the fluxes, second one slag entrapment third one longitudinal cracks, fourth one transverse cracks, fifth one star cracks, sixth one longitudinal depressions seventh one transverse depressions, eighth one blowholes, ninth one interruption in the physical continuity and the tenth one shrinkage cavity. Now let us see all these one by one first let us see the sticking of the fluxes yes.

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STICKING OF FLUXES

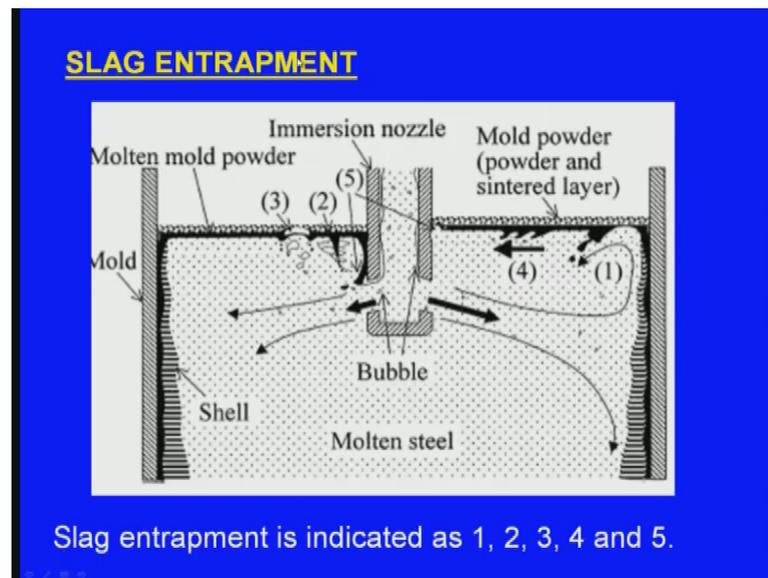
The diagram illustrates the sticking of fluxes in continuous casting. It is divided into two parts: 'Normal Shell Formation' and 'Shell Distorted by Sticking'.

Normal Shell Formation: Shows a cross-section of a solidifying shell with a smooth, uniform surface. A corresponding graph plots Temperature (Y-axis) versus Time (X-axis), showing a smooth, continuous curve that levels off as the shell forms.

Shell Distorted by Sticking: Shows a cross-section of a solidifying shell where fluxes (marked with 'x') are embedded in the shell, causing it to become distorted and cracked. A corresponding graph plots Temperature (Y-axis) versus Time (X-axis), showing a sharp peak in temperature, indicating a disturbance in the casting process.

Sticking of the fluxes will be like this, yes this is the what say mould this is the mould and this is the molten metal as the molten metal is going down yes this red colored one indicates the solidification solidified portion. Now what happens if there is not sticking it looks like this. So, this is the normal shell formation, but shell distorted by sticking what happens here the shell is sticking to the mould, if that be the case it becomes like this. So, here there is a damage to the shell. So, this is due to the sticking of the fluxes.

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Next one slag entrapment and here we can see slag entrapment is indicated as 1 2 3 4 5 here we can see 1 2 3 4 5 these places the slag is entrapped. So, because of that these slag entrapments they cause some discontinuities in the cast billet means slag is not properly removed from the molten metal.

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LONGITUDINAL CRACKS

They appear due to:

- the unevenly removal of the heat in the mould.
- turbulent flow of metal and a meniscus level variation in the mould.
- secondary cooling too intense or uneven.
- unequal, advanced wear of the mould that leads to a different thermal conductivity coefficient.
- high casting temperature.
- inappropriate behaviour of the casting powder.

Next defect is the longitudinal cracks, they appear due to the unevenly removal of the heat in the mould, they also appear due to turbulent flow of the metal and a meniscus level variation in the mould. They also appear due to secondary cooling too intense or uneven they also appear due to unequal advanced wear of the mould that leads to a different thermal conductivity coefficient, and they also appear due to high casting temperature finally, they also appear due to inappropriate behavior of the casting powder. So, these are all the factors that are influencing the longitudinal cracks.

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Typical appearance of longitudinal cracks

So, this is the typical appearance of longitudinal cracks they look like this, you see longitudinal cracks means parallel to the axis of the bar this is the longitudinal crack.

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TRANSVERSE CRACKS

The causes that give rise to transverse cracks are:

- the thermal stresses due to the uneven solidification of the crust.
- meniscus level variation.
- friction of the strand in the mould.

Next one let us see the transverse cracks, this transverse cracks right are due to the following right the thermal stresses due to the uneven solidification of the crust. Next one meniscus level variation, next one friction of the strand in the mould. So, these contribute to the formation of the transverse cracks.

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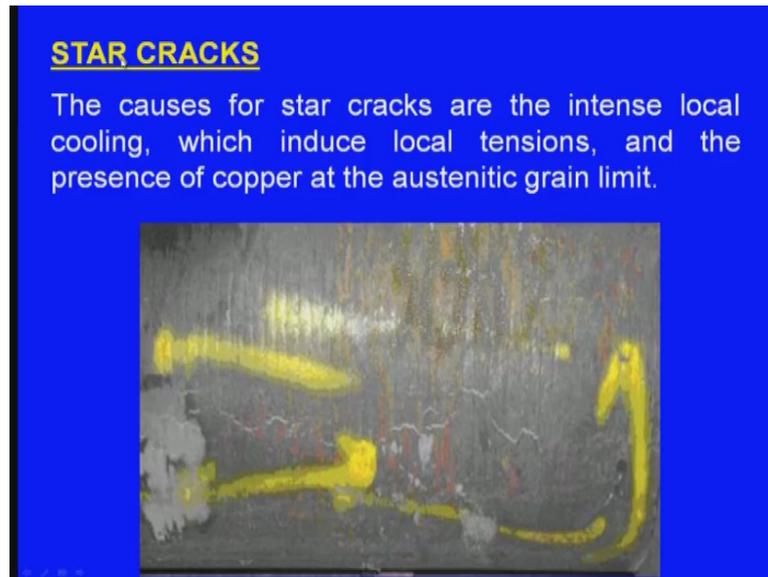


Typical appearance of transverse cracks

Let us see the typical applications appearance yes transverse in the case of the previous one, the longitudinal cuts means those cracks are parallel to the axis of the bar, but here this cracks are perpendicular to the axis of the bar.

So, these are known as the transverse cracks next one.

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The next defect is the star cracks. The causes for the star cracks are the intense local cooling which induce local tensions and the presence of copper at the austenitic grain limit. These cracks they look like what say star they have the star appearance you can see here they look like a star they are they are not perpendicular to the axis, they are not parallel to the axis, but in multi directions they develop cracking. So, this is the star crack next one Longitudinal depressions.

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LONGITUDINAL DEPRESSIONS

The longitudinal depressions are caused due to:

- the unequal development of the marginal crust;
- the steel level fluctuation in the mould and a too large quantity of melted flux, located in the space between the mould wall and the strand;
- the turbulent steel flow at the sub-meniscus level;
- the uneven and advanced wear of the mould, which results in a different coefficient of thermal conductivity.

So, this is another defect, the longitudinal depressions are caused due to the following factors. The unequal development of the marginal crust second factor the steel level fluctuation in the mould and a too large quantity of the metal flux located in the space between the mould wall and the strand next factor the turbulent steel flow at the sub meniscus level, and the next factor is the uneven and advanced wear of the mould which results in a different coefficient of thermal conductivity.

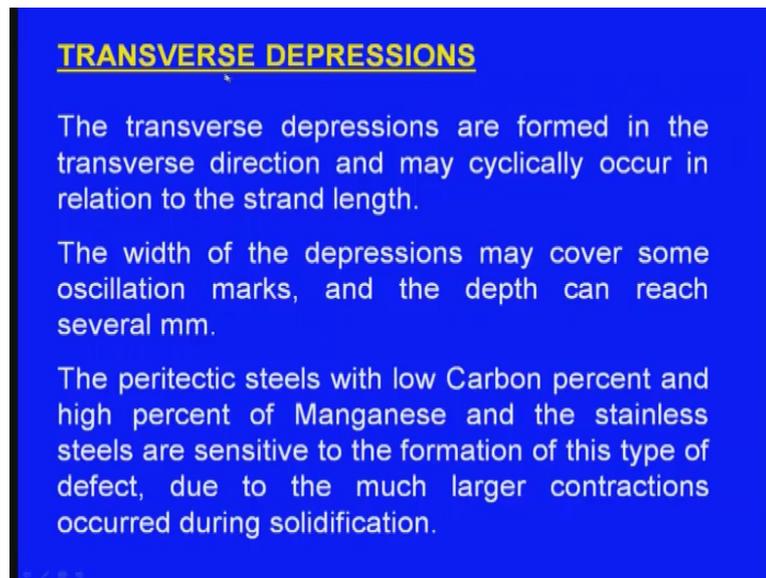
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Typical appearance of longitudinal depressions

So, these are the typical appearances of longitudinal depressions means these are the depressions parallel to the x of the job or x of the bar. So, you can see here these are all the depressions, but their orientation is parallel to the axis. So, we are calling them as the longitudinal depressions next one.

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TRANSVERSE DEPRESSIONS

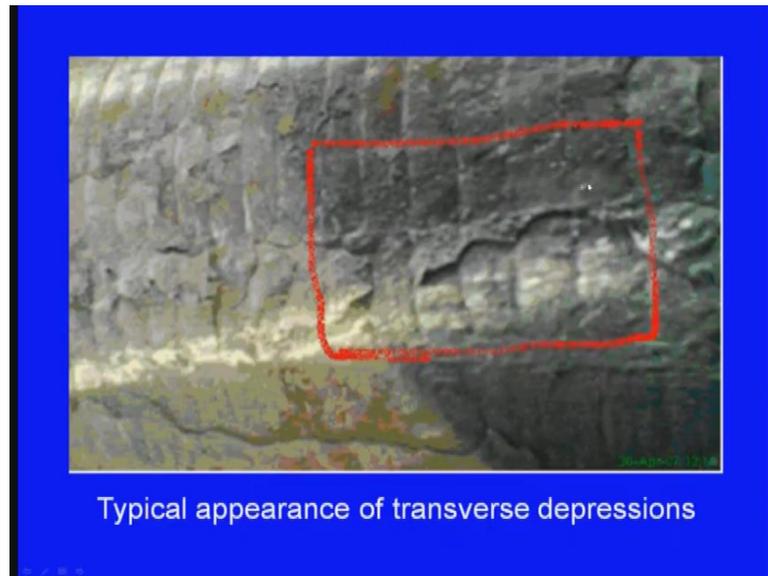
The transverse depressions are formed in the transverse direction and may cyclically occur in relation to the strand length.

The width of the depressions may cover some oscillation marks, and the depth can reach several mm.

The peritectic steels with low Carbon percent and high percent of Manganese and the stainless steels are sensitive to the formation of this type of defect, due to the much larger contractions occurred during solidification.

Transverse depressions; the transverse depressions are formed in the transverse directions and may cyclically occur in relation to the strand length. The width of the depressions may cover some oscillation marks and the depth can reach several millimeters. The peritectic steels with low carbon percent and high percent of manganese and the stainless steels are sensitive to the formation of this type of defects due to the much larger contractions occurred during solidification this is the typical appearance of transverse depressions.

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Next one blowholes.

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BLOWHOLES

Blowholes can arise due to the following:

- insufficient steel deoxidation (presence of gases: hydrogen, nitrogen, oxygen).
- humidity of the casting powder.
- quality of the casting powder (% carbon, viscosity, basicity) - quantity and uniformity of its distribution.
- variation of the steel level in the mould, existence of moisture in the refractory lining of the tundish.
- the presence of argon entered in the mould during the injection of argon for filling the nozzle.

Blowholes can arise due to the following, insufficient steel deoxidation presence of gases hydrogen nitrogen and oxygen. Next one humidity of the casting power, quality of the casting power percentage carbon viscosity basicity quantity of uniformity of its distribution next one variation of the steel level in the mould existence of moisture in the refractory lining of the tundish next one the presence of argon entered in the mould during the injection of argon for filling the nozzle.

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These are the typical appearances of blowholes next one.

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INTERRUPTION IN THE PHYSICAL CONTINUITY

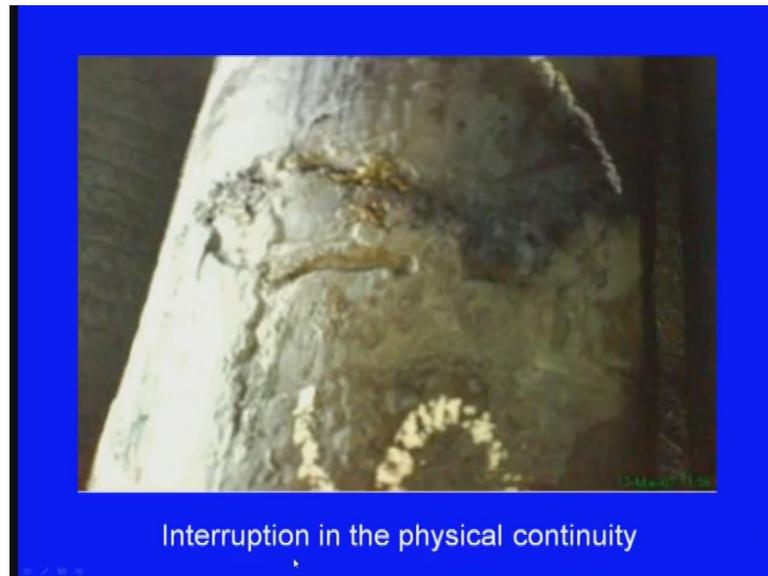
Interruptions in the physical continuity is caused by a short interruption of the casting process.

This defect occurs due to sudden changes in casting speed, caused by the variations of steel temperature in the tundish, by the variations of steel level in the mould, or by the variations of casting mode.

It can be removed by shortening the bar that contains it.

Interruption in the physical continuity is the next defect. So, this is caused by a short interruption of the casting process and this defect occurs due to the sudden changes in casting speed caused by the variations of steel temperature in the tundish by the variations of steel level in the mould or by the variations of casting mould it can be a removed by shortening the bar that contains it yes this is the.

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What say what say physical interruption in the physical continuity you can see here this is the interruption.

Next one shrinkage cavity.

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SHRINKAGE CAVITY

The causes that produce this defect are: high casting temperature, high extraction speed and intense secondary cooling.

Shrinkage cavity represents a gap of material, visible in the cross section at the end of a bar.

It can be removed by cutting the end of the bar, and the defective portion is rejected.

The causes that produce this defect are high casting temperature, high extraction speed and intense secondary cooling. Shrinkage cavity represents a gap of material visible in

the cross section at the end of a bar, shrinkage cavity can be removed by cutting the end of the bar and the defective portion is rejected.

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This is a typical appearance of a shrinkage cavity, next one let us see some important terms in the continuous casting.

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Liquid Steel Transfer

There are two steps involved in transferring liquid steel from the ladle to the moulds. First, the steel must be transferred from the ladle to the tundish. Next, the steel is transferred from the tundish to the molds.

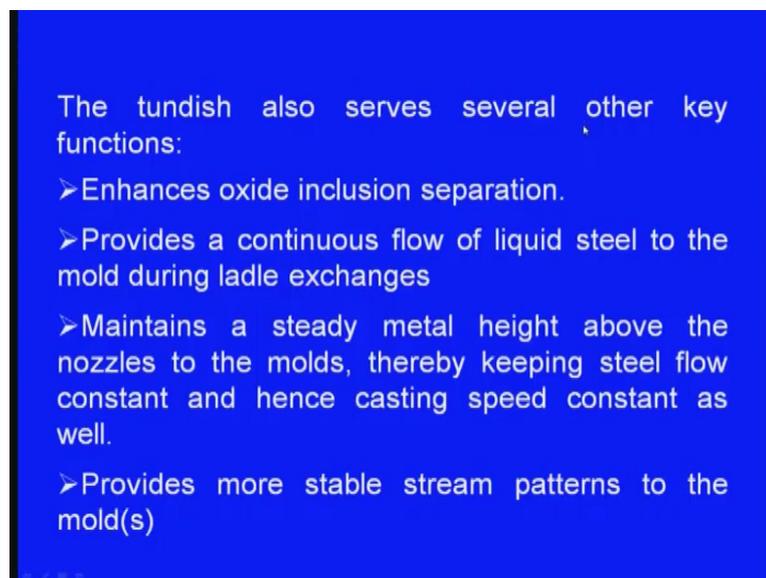
Tundish Overview

The shape of the tundish is typically rectangular, but delta shapes are also common.

One is the liquid steel transfer. So, there are two steps involved in the transferring liquid steel from the ladle to the moulds first, the steel must be transferred from the ladle to the tundish.

Next the steel is transferred from the tundish to the mold, next one tundish overview what is this tundish? Tundish is a local reservoir which accommodates the molten metal before sending it through the mold. So, the shape of the tundish is typically rectangular, but delta shapes are also common the tundish also serves.

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Several other keys functions one is the it enhances oxide inclusion separation. It provides a continuous flow of liquid steel to the mold during ladle exchanges, even though the ladle sometimes ladle fill the molten metal and it go out of that time there should not be any interruption that is why the what say tundish acts as the local reservoir. Next one maintains a steady metal height above the nozzles to the molds thereby keeping steel flow constant and hence the casting speed constant as well provides more stable stream patterns to the molds.

Next one mould.

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Mould

The main function of the mold is to establish a solid shell sufficient in strength to contain its liquid core upon entry into the secondary spray cooling zone.

The mould is basically an open-ended box structure, containing a water-cooled inner lining fabricated from a high purity copper alloy.

The working surface of the copper face is often plated with chromium or nickel to provide a harder working surface, and to avoid copper pickup on the surface of the cast strand, which can facilitate surface cracks on the product.

The main function of the mold is to establish a solid shell sufficient in strength to contain its liquid core upon every entry into the secondary spray cooling zone. The mould is basically an open ended box structure containing a water cooled lining inner lining fabricated from a high purity copper alloy. The working surface of the what say copper face is often plated with chromium or nickel to provide a harder working surface and to avoid copper pickup on the surface of the cast strand, which can facilitate what say surface cracks on the product next one another important term is the mould oscillation.

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Mould Oscillation

Mould oscillation is necessary to minimize friction and sticking of the solidifying shell, and liquid steel breakouts, which can wreak havoc on equipment and machine downtime due to clean up and repairs.

Oscillation is achieved either hydraulically or via motor-driven cams or levers which support and reciprocate (or oscillate) the mould.

Friction between the shell and mould is reduced through the use of mould lubricants such as oils or powdered fluxes.

Mould oscillation is necessary to minimize friction and sticking of the solidifying shell and liquid steel breakouts which can wreak havoc on the equipment machine downtime due to clean up and repairs.

Oscillation is achieved either hydraulically or via motor driven cams or levers which support and reciprocate the mould. Friction between the shell and mould is reduced through the use of the mould lubricants such as oils or powdered fluxes. So, we are about to complete and before we windup let us review what we have learned. We have learned the types of the continuous casting process, the vertical continuous casting process, the curved continuous casting process horizontal continuous casting process and the strip continuous casting process. Vertical continuous casting process is divide into vertical downwards continuous casting and also vertical upward continuous casting process. So, these are the classifications of the casting continuous casting process we have learned.

Next we have learnt the different types of the electromagnetic stirring what say process we have seen. There are three types of EMS applications one is the mould EMS, second one is the secondary cooling zone EMS, third one is the final solidification zone EMS we have learnt in this lecture. Next one we have also seen the functions of the mould fluxes we have learnt next one finally, we have learnt about different what say continuous casting defects with this we are closing this lecture the continuous casting process.

Thank you.