Steel Quality Role of Secondary Refining and Continuous Casting

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Module – 7
Lecture – 41
Typical Cracks and Defects: Part II

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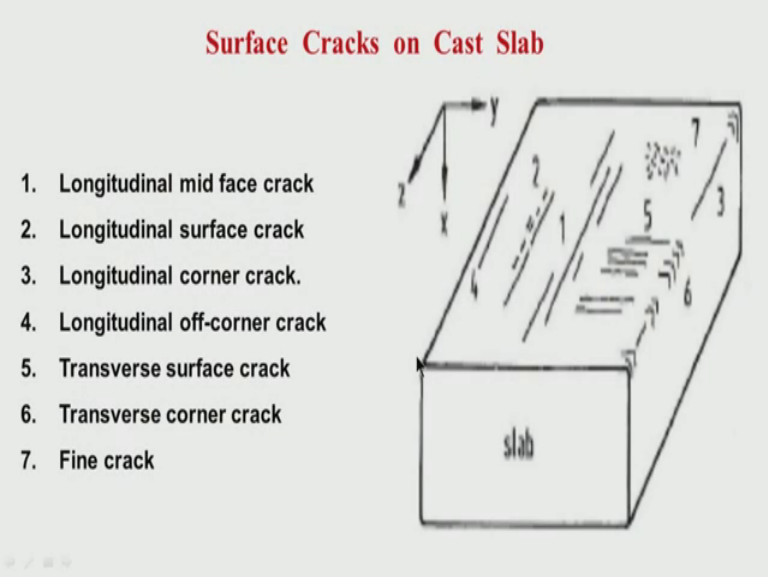

What is basically slab? Slab means basically the width is more than the thickness then we call it a slab. So, width can be say about one meter and more than a meter and maybe 1500 millimeter; that means, 1.5 meter, it can be 1 meter and the thickness may be only 200 millimeter, 150 millimeter. So, width is much more this is the width and this is the thickness, if the width is more than the thickness we call it a slab. So, this is the longitudinal direction Z, Z is the longitudinal direction y is the width direction and this is the thickness direction X.

So, now let us see what are the cracks surface cracks on cast slab; that means, cracks will visible on the surface of the slab itself that is why they are called surface cracks. So, one is the longitudinal mid face crack, this is the one this is around the middle area of the middle area of the surface broad surface this is called the narrow surface, this is small surface this is the broad surface you may have a crack you know in the mid surface of

the narrow surface also, but relatively incidence is more on the broad surface that is why we have shown it on the broad surface.

So, it is a longitudinal mid face crack on the broad face now two again it is not in the mid face region any of the region, but direction is longitudinal. So, we call it simply longitudinal surface crack now what is 3? This is the corner. So, if the crack formation has taken place at the corner and the direction is longitudinal along the casting direction. So, we call it longitudinal corner crack. So, now, look at the location this four this was mid face this was any you know any location 3 was at the corner four is we call it off corner why off corner? Slightly away from the corner.

So, off from the corner. So, is called off corner, but it is off corner surface crack, but longitudinal direction. So, longitudinal off corner crack on the surface. So, this is this one now come let us come up to transverse cracks, you look at this cracks this are its on the surface, but at transverse directions perpendicular to the longitudinal direction. So, we call them transverse surface crack because around the surface. Now look at this cracks at the corner, but in transverse directions these are we call them transverse surface crack, but here these are again transverse direction, but location is corner.

So, we the 6. So, we call them transverse corner crack look at this crack look at this crack look at this cracks, these are transverse corner cracks, and this is where transverse cracks at the surface this is also surface, but at the corner. Now look at this other types of cracks I have mentioned like in (Refer Time: 04:01) grounds also you can have some fine cracks not having any particular orientation neither longitudinal not transverse. So, we call them fine cracks, sometimes we may call them spider cracks also if they are small oriented in different directions. So, like billet bloom and rounds in slab also you can have lot of surface cracks. So, depending on their orientation they can be longitudinal, they can be transverse and they can be at the corner, they can be at mid face region, they can be at the off corner region and they can be now fine cracks not having any particular orientation neither longitudinal not transverse.

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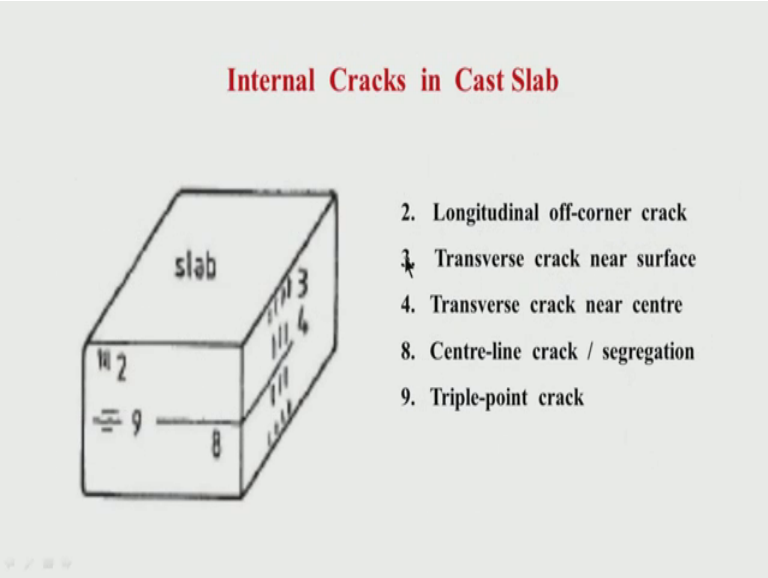

So, now let us come to internal cracks in cast slab. I have talked about the surface cracks in cast slab now let us come to internal cracks in cast slab is the width of the slab, this is the thickness this is the length of the slab. So, we will we have to look at the interface we have to look at the cross section, you cannot see slabs on the surface. So, this is one section this is another section this is a section of the internal crack mean. So, you have to say at the section. So, this section cross section let us see what are the cracks; this location you will find it is not at the corner it is off corner. So, we call it longitudinal off corner we are saying only the tress if we cut another section here if you see that surface cross section we will see the tress somewhere there.

So, that is why it is a longitudinal in the crack is along this this direction around us, but at the internal location. So, we call it longitudinal of corner crack. Now if you have a crack and this near the corner if you have a tress then it would have been corner crack internal crack now longitudinal corner crack two is basically longitudinal off corner crack, I am not shown one because I had shown it earlier. So, in that is near the corner if it is a longitudinal crack somewhere here then we can call it corner longitudinal corner crack now then we can have a transverse crack near surface. So, this 3 locations is near the surface that is not exactly surface of surface slightly in internal locations.

So, maybe we can call it a subsurface or near surface. So, these are transverse because directions are perpendicular to the longitudinal direction. So, transverse is 3 here again

you have transverse cracks, but near the center this was near the surface near the center and this a near the surface. So, depending on the location you are givings some nomenclature you have and the generation of the cracks also you might be it is will be helpful to understand how the cracks are formed if you know what is the if there is a transverse we will longitudinal at what was the location, that is what stage they are formed whether it was during you know casting stress solidification stage or after solidification again when the shell is going through a transverse region, there made be crack formation because those are you know brittle region.

So, there is a possibility of crack formation they are also. So, now, let us look at center line crack or segregation. This one you have taken a section and you looking at the center. So, you may have cracks you may have lot of segregation. So, I have telling them center line crack or segregation sometimes they are combine together sometime separately you can have crack you may not have crack, but segregation is normally present always crack you will have if you have a relatively bad casting, then you have relatively coarse construction you know solid super hot was high. So, you are the same columnar zone is extending from the surface to the center, then you have crack you have lot of segregation is a bad central area.

So, super hit place a big role here, super hit that is why has to be low to avoid high intensity of crack and segregation formation at the centre line. Now we might have a what is the triple point area triple point is you have the centre and you have a diagonal. So, when the diagonal is meeting the central this is called the triple point. Triple point means solidification front one solidification front is generating from here moving to the centre another solidification from this surface moving towards here among the bottom also another solidification front is moving towards the centre. So, all the 3 fronts solidification fronts are meeting at the triple point. So, this triple point like the central like the diagonal is a relatively high defect area, this area is prone to have lot of defects because all the solidification fronts are meeting like grain boundary normally is having more defect compared to the grain interior.

So, here you know the diagonal the central area and the triple point area you have more defects compare to the normal area of the casting. So, this areas relatively are weak because of lot of defects are there. So, the possibility of crack formation are also more. So, this is called triple point crack, crack at the triple point. So, you can have crack at the

triple point you can have crack at the you know central line, if had there been a crack in this direction that I had shown it for the internal crack you be later bloom. So, it is a diagonal crack. So, depending on the location if is at the diagonal location it is a diagonal crack, if it is at the centre line we call a centre line crack, if it is at the triple point.

We can call it triple point crack if the location is near the corner not a exactly at the corners slightly off from the corner, you call it off corner longitudinal crack if you have crack at the corner itself then we call it longitudinal corner crack.

If it is on the surface it is on the surface crack, if it is interior somewhere here in, but at the interior is at the subsurface location then we call it corner longitudinal crack internal location. So, these are the locations where you can have internal crack, these are the cracks which we see on the surface itself again depending on the you know orientation, it can be longitudinal, it can be transverse it can be you know fine cracks, but there is no orientation very small you know and if it is at the corner we call it corner crack, if it is from off from the corner we call it this 4 we call it off corner crack, but because of the orientation of the longitudinal direction we call it longitudinal of corner crack, we may have mid face crack, at the mid region of the surface mid face crack we may have normal surface cracks, you know at location not exactly at the made not at the corner, but any location we call it you know normal the orientation is longitudinal.

So, longitudinal surface crack we may have transverse crack surface crack you may have transverse corner crack at the corner location this is a normal surface cracks this is a normal you know corner cracks . So, depending on what is there orientation what is there location we can give different name to the cracks this I have mentioned yeah.

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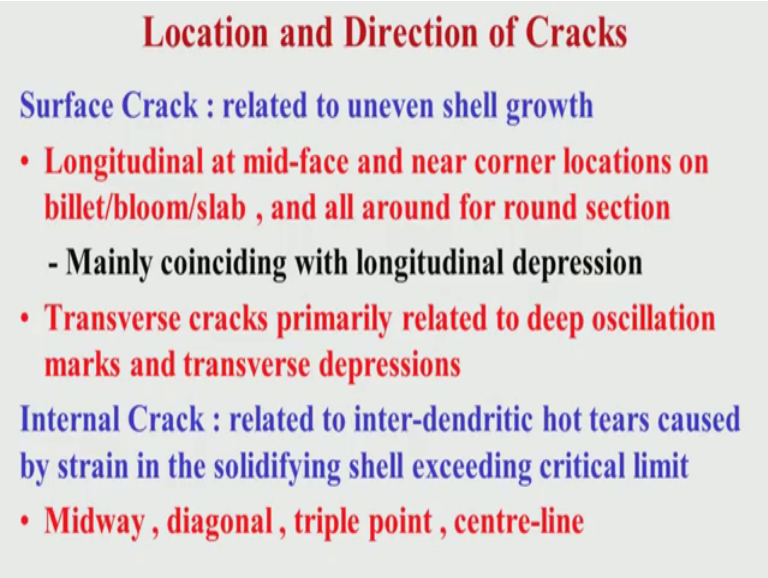

And this transparency that location and direction of cracks is very important; surface cracks they will basically related to are even shall grow that shown lot of surface cracks transverse or longitudinal both on slab surface as well as on billet bloom or now. So, though surface cracks are basically forming due to uneven shell growth, it can be at you know longitudinal direction, it can be transverse direction the location can we mid face near corner you know.

So, all sorts of locations can be there. So, they are mainly coinciding with longitudinal depression not always sometimes you can find cracks, but not depression if the casting condition is not you know good, if there is a sudden fluctuation in casting speed sudden fluctuation in heat transfer due to some reason you might get crack, but you may not get depression. So, but normally what is found is if they have longitudinal depression you will always find some cracks either along the depression or at internal cracks interior to the deep you know just penetrate the depreciation that is below the depression. Though surface cracks can be longitudinal at mid face near corner, you know I have shown different directions and locations, and then we can have transverse cracks normally related to deep oscillation marks I have mentioned. Oscillation marks are in transverse direction if the oscillation marks are deep then it is a real defect, if there oscillation marks are shallow it is not call it defect because what is going to happen to that cast product if you have shallow oscillation marks, any shall defect because this will be heated normally put in the (Refer Time: 15:24) furnaces before rolling.

So, in the during (Refer Time: 015:28) there is a formation of scale and so, for very shallow surface defects where the depression or crack. If this is really shallow not very deep they will be going along with the scale, but if you have a deep oscillation mark if you have a deep crack, if you have a deep you know depression whether a transverse or longitudinal they will not go along with the scale. So, during rolling also they will remain and they will generate lot of defects. So, what is important is to avoid deep oscillation marks, this you can avoid as I have mentioned by controlling oscillation parameters by controlling the negative strip time. So, it is possible to control deep oscillation marks because normally if you have deep oscillation marks. You can have transverse depressions and transverse cracks and also if I have transverse depressions you can have transverse cracks.

So, you have to take care of this, now I have mentioned that for internal cracks you may have lot of internal cracks I have shown. So, they are related to inter dendritic hot tears I have mentioned internal cracks I have different locations at corner locations at central location, triple point location, at subsurface locations and on corner or rough corner. So, they are inter dendritic hot tears; that means, at inter columnar or inter dendritic locations, where the strength is low transverse you know the ductility is low those areas they are crack formation is more probable, there is high possibility of formation of cracks on those areas. So, inter dendritic hot tears caused by strain in solidifying shell.

So, whenever the strain is exceeding the limit, we will have crack formation inter dendritic areas. So, we call it hot tears I have shown it can be at midway it can be diagonal, it can be triple point, it can be central line. So, the possibilities of crack formation at their at different locations at the surface internal I have tried to tell you what are the possible reasons surface cracks related to uneven shell growth. So, the heat transfer in the mould surface cracks normally you find either at the initial stage of solidification or it might also for me if you have lot of uneven surface in chemistry like 0.1 percent carbon; that means, if the you know surface uneven lot of depression is there.

So, grain sizes are coarse. So, if the grain sizes are coarse, grain boundary areas are relatively less. So, even at low temperature; that means, around 600 to 700 there a possibility of formation of nitrates of aluminium, niobium you know. So, those we will try to form at the relatively less ground bend areas. So, the density of the precipitates we will be more if you have coarse grain. So, there is a possibility of crack formation

because of that. So, on the surface cracks can form due to two reason because of uneven shell growth or if the surface is having coarse grain coarse structure then at the brittle temperature at the low temperature brittle at the zone, which is around 600 to 700 this uneven shell growth is happening at high temperature during the stage up solidification, but the low temperature brittle zone which is around 600 to 700.

They are cracks miles might form because of the nitrate formation of aluminium narmium or vanadium. So, they are coarse grains is the problem. So, that we have to control the heat transfer in such a way in the mold so, that we do not have too much of depression we do not have too much of surface roughness, if you do not have surface roughness then we do not have coarse grains. So, we do not have this low temperature you know brittle zone you will not be there because the nitrates we will be forming along the grain boundaries of the finer grains which is quite large area. So, the densities of formation of the you know nitrate will be less, and the brittleness also will be relatively less.

So, the reasons for surface crack formation at two fold one is uneven shell growth from there either during solidification or during at low temperature in the solid study itself that can we crack formation. But internal cracks they are basically inter dendritic; that means, they are basically hot tears, they can form in different type of chemistries. If the structure is coarse you know if it is the columnar zone is more due to high super heat then you can have this hot tears. So, if the structure is coarse in the inter dendritic areas there is a possibility of hot tears, and the strain is exceeding the you know critical limit then these areas inter dendritic areas are prone two formation of crack, which may format different regions made way diagonal.

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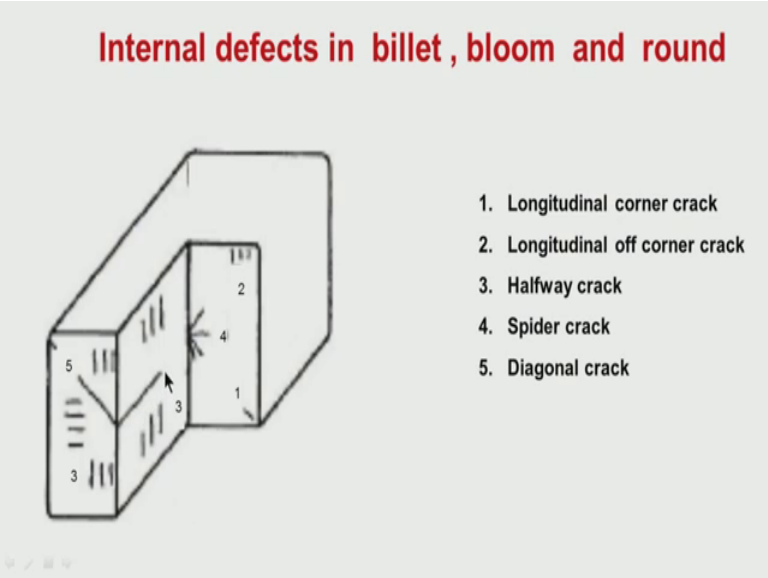

As I have shown it here it can format the central region, it can format the diagonal, it can format the triple point, it can format different locations of corner, it can format corner these are weak areas. So, there is a possibility of formation of those internal cracks because of hotspot formation because of tear intern dendtritic region which are relatively poor in strength and the slab also of shown you see these areas either central on the triple point areas or at the corner or off corner even at the you know mid locations, traverse crack either near centre or near surface and depends at which area of the casting during after continuous after solidification, if these areas are you know just solidification is complete. Suppose solidification is complete at this area. So, there is a formation if there is too much of strength that area is going to generate crack. When solidification has gone certain gone ahead. So, even the central region because of the coarseness of the structure you can a crack you can a crack at the diagonal area you can a crack at the triple points again because of coarseness of the structures.

So, these are called internal cracks at different locations either triple point centre it can be longitudinal depends on the orientation, it you know why longitudinal crack we will form and why transverse crack we will from try to understand the reason for that. Longitudinal crack we will from let us go to the surface then it will be better to understand longitudinal crack we will form when there is a transverse stress during casting or during cooling if the stress is transverse you have longitudinal crack transverse stress means stress is according in this direction in this direction there is possibility of

longitudinal track formation, but if you have a longitudinal strain or stress then you have a transverse crack. So, depends on the strain direction, it strain can be in the during solidification you can I have mentioned you can I have strain at different point of casting at that point different point of the caster, different location of the caster.

You can have due to bending there can be mechanical strain then there is a shrinkage the direction is something you know in shrinkage direction will be away from the cast found. So, sorry it is towards there cast found; that means, it is transverse is nature. So, if there stress is transverse in nature you may have an longitudinal crack, that is why what I have mentioning is the possibility of having longitudinal crack is there when you are the casting is just taking place in the mould because these are formed mostly in the mould area either in the mould there may initial stage of solidification or as I have mentioned for certain chemistry we have very coarse structure. So, because of the coarse structure the cast grains are coarse the grain moment areas are less. So, at temperature of 600 to I mean 700; that means, when you are cooling it there is a possibility if you cannot avoid that particular area, if you are if you pass that area that temperature area in a relatively it take it takes long time for the shell to be in that, you know brittle temperature zone of 600 to 700 you may have generate cracks because of the formation of nitrates.

So, coarse grain is the culprit there here the culprit is formation of tenancy for the formation of depression or tendency for the formation of shrinkage mode the shrinkage mode we will the possibility of formation of such cracks surface cracks. But if you have a you know you know longitudinal direction of tension then you might have transfers crack you might have transverse crack at the re region of deep oscillation marks, you may have transverse crack in the region of transverse depression. So, everything is depending on what is the direction of the strain. So, the direction of the strain if it is transverse it will generate longitudinal crack, if the direction of the strain is longitudinal it will generate transverse crack.

So, I have try to cover what are the possible reasons of crack formation at the surface as well as the interior. So, internal crack formation and surface crack formation they are two broad categories of solidification characteristics either it is prone to sticking or bulging there is one type of characteristics another is it is prone to depression formation. So, if you have sticking tendency or bulging tenancy you have to tackle it in a particular way during casting,+ if it is a if the grid is prone to surface roughness prone to you know

surface defects surface roughness; that means, surface depression whether it is longitudinal or transverse, does not matter if you have surface depression prone to depression; that means, a lot of depressions might form at different location different orientations.

So, you have to tackle it in a different way you have to tackle it in the mould by having uniform cooling throughout the periphery of the mould. So, their heat transfer is the main issue, you should have uniform heat transfer in such grades peritectic grades where the carbon is around 0.1 or in 3 0 4 stainless steel where the nickel equivalent by chromium equivalent is around 0.55. So, those areas we have to be those chemistry is those grace we have to be careful heat transfer should be uniform. How do you do that you should have proper characteristic casting powder, after melting you should control the heat transfer in such a way that the formation of surface defects are less.

So, two brought types of defects rather two broad types of characteristics of solidification either it is taking in the mould or depression in the mould. If it is taking I have to tackle it by controlling the friction between the mould surface and the solid shell and if it is depression formation we have to tackle it through heat transfer inside the mould by using suitable characteristics of the powder. So, that the slag mould slag you can controlled uniform heat transfer and I have uniform heat transfer, you can in part uniform heat transfer in the mould.

So, depending on the characteristics you have to choose the casing parameters, what would be the oscillation parameters again depends on, what type of chemistry you are using what should be the secondary cooling intensity or distribution of cooling in the secondary cooling area it depends again on the type of grids. Grids which I have prone to have more internal cracks; that means, what the relative you know surface relative strength of the shell is less; that means, I am talking of you know very low carbon either delta ferrite or very high carbon where do I austenite, but thing shell.

So, they are the formation of possibility of formation of crack because of the less strength of the shell poor strength of the shell either because of the characteristic this is delta or if it is very thin, then also how to tackled it you know that is very important, you should have more up int a more intensity of solidification more intensity of secondary cooling is required in such grids. So, these issues are important and based on the intrinsic

solidification characteristic of I had a mentioned of the two types either depression type or sticking type these are intrinsic characteristics based on the chemistry of the grid. So, based on these intrinsic characteristics you have to design the casting parameters so, that these are taken care of to a large extent this problems are taken care of to a large extent.

Thank you very much.