

Steel Quality Role of Secondary Refining and Continuous Casting
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Module – 07
Lecture – 40
Typical Cracks and Defects: Part I

What are the types of cracks which will form? It can form on the surface of the cast product which you can see.

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Location and Direction of Cracks

Surface Crack : related to uneven shell growth

- **Longitudinal at mid-face and near corner locations on billet/bloom/slab , and all around for round section**
- **Mainly coinciding with longitudinal depression**
- **Transverse cracks primarily related to deep oscillation marks and transverse depressions**

Internal Crack : related to inter-dendritic hot tears caused by strain in the solidifying shell exceeding critical limit

- **Midway , diagonal , triple point , centre-line**

So, we call them surface crack these are basically related to uneven shell growth I have mention that sticker type of grade do not indicate uneven shell growth, but when you have depression type of characteristic; that means, for an 0.1 percent carbon the so called patriotic grade or 3 0 4 standard steel we have uneven shell growth along the you know mould that is large area of the periphery of the mould.

So, along this periphery the shell growth is non uniform for depression type of grades. So, because of that there is a possibility of surface crack formation. Now what are the directions of the surface cracks they can be longitudinal, they can be at the mid face, they can be near the corner locations, I will indicate in figures how do they look like, but physically I will tried to here tell you what are the types of cracks, what are the locations the direction of cracks location and direction both are important. Location means where I

have the surface or the interior, direction means whether there in the longitudinal direction; that means, along the direction of the casting, what in the transverse direction at perpendicular to the casting direction or at corner location it can be at the corner location, it can be you know at other locations also.

So, we will see those cracks. So, the longitudinal cracks that it can be at mid face, it can be near corner locations on billet surface, bloom surface or slab surface and all around for round section. In round section you do not have a corner. So, it can be at any location on round section in fact, round section casting is very difficult. Round section it is very difficult to have you know uniform shell growth. So, we have to be very careful when you are casting a down otherwise there will be lot of surface crack formation at different locations all around the round sections.

Now, these longitudinal cracks sometimes or most of the time they coincide with the longitudinal depression. I have told you there is a possibility of longitudinal depression in depression grades because of uneven shell formation. So, if you have longitudinal depression normally you find beneath those depressions there will be cracks. So, longitudinal cracks they can coincide with longitudinal depression, now you can have transverse cracks as well where do the transverse cracks form transverse, cracks means the orientation of the cracks are perpendicular to the casting direction. So, they are perpendicular to the longitudinal direction. So, the transverse cracks primarily they are related to deep oscillation marks and transverse depressions.

I have told you that normal oscillation marks do not constitute a defect in cast product. Since you have oscillation during continuous casting will you will always have transverse oscillation marks, this oscillation marks at transverse direction; that means, perpendicular to the casting direction. So, this oscillation marks if they are not deep they do not cause any problem they do not constitute any defect, but if you have a deep oscillation marks it depends on what I had mentioned earlier. It depends on what are the type of oscillation you are giving what is the amplitude of oscillation, what is the frequency of oscillation, I have mentioned is negative strip time, the concept of negative strip time, if the negative strip time is more you have very deep oscillation marks.

So, your objective will always be to control deep oscillation marks by controlling negative strip time. So, particularly for the depression type of grades where the tenancy

will be to have deep oscillation marks you can control it by manipulating the oscillation characteristics like amplitude like you know frequency these are the important issues. So, transverse cracks primarily related to primary located at deep oscillation marks and transverse depressions. Now these are surface cracks which you can see on the surface of the cast product that is bloom, round, billet or slab, but there are certain cracks inside the casting which you cannot see how you can see those cracks.

If you take a transverse section then you can see those cracks, sometimes some cracks will be visible if you take a transverse section. On the surface it is very easy to see just like the cast product has come out of the caster, after it gets cooled or even during if there it that cracks are quite you know large and dimension you can see it when the during the casting stage itself and the final stage of casting, when the cast product is horizontal when its moving horizontally then on the top surface you can see there is a cast that there are cracks or there are depressions, and there will be this defects even at the bottom surface also even on the narrow face also.

Because what he was seeing is only the top surface. So, on the surface you can see the defects, but internal cracks or internal defects you cannot see normally on the cast product. So, what we have to do we have to take a transverse section, whether it is x y section or it is a z y section it any transverse section, it can be longitudinal transverse section it can be you know width wise transverse section. So, whatever transverse section; that means, either you take it width is too thickness that ratio that surface or l t surface or w width, w t surface order l t surface that there can be two cross section. So, you have to see those cross sections then only this internal cracks will be revealed.

So, this related to inter dendritic why do they form the related to inter dendritic hot tears I have mentioned to you that around solidification end temperature there is a beetle temperature region, during the inter dendritic; that means, inter columnar regions which I related a week. So, we call them hot tears there will be formation of crack in those inter dendritic inter columnar regions. So, we call them internal crack. Why do they form if there is strain in the solidifying shell strain if it is limited within some limits that was it is less than the critical value then the crack formation can be controlled, but if the strain formation strain generation rather is relatively high the magnitude is relatively high then you can have which is above the critical limit you can have cracks internal cracks, in the

or the hot tears we call it some people call it in the inter dendritic regeneratively high temperature there are forming.

Now, what do they form then again they can form; that means, we call it midway; that means, at the mid-section you can form, they can form at the diagonal region you know what the solidification fronts are meeting that is a relatively weak area. So, inter columnar area there it can form, it can form the triple point again it is a weak area triple point basically means what, define solidification points are meeting there is called triple point area then it can form at the centre line these again are weak areas.

I will come I will discuss in details what is the problem for centre line defects it can be crack, it can be you know segregation because the what is central line this area is solidified at the end; that means, this area is relatively rich in solute because of segregation. There will be segregation I have mentioned in all still whenever solidification is taking place, because they are allowing elements in steel and all allowing elements all solutes will segregate will cause segregation.

But some elements will segregate more like phosphorus and sulphur some other elements like manganese silicon will segregate less, but nevertheless there is segregation for all alloying elements and which area we will have more segregation the area of casting which is solidified at the last because that liquid we solidified at the last became relatively more rich in all alloying elements, whether it is carbon, whether it is manganese, whether it is silicon, whether it is phosphorus, whether it is sulphur, that particular area will have more enrichment. So, we have centre line problems there may be crack there may be segregation. So, internal crack at the centre line is a problem you know because of the coarse cast structure we can have you know crack at the centre line if the you know super heat it is more that is going to happen if the super heat is more columnar zone columnar zone extends almost towards the centre portion of the casting.

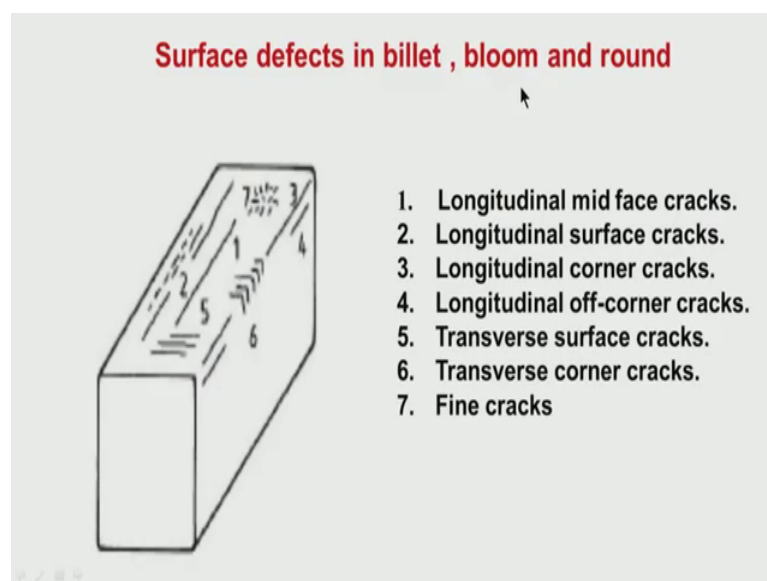
If the super heat is less there will be (Refer Time: 11:06) zone in the central region of the casting; that means, the area of the cast which is solidifying at the last normally should have equal zone, if the super heat is less is about 10 20. But if the super heat is more say 40 or 45 or 50 then you may have columnar zones extending from the surface of the cast product till the central region; that means, it is throughout columnar structure there is no (Refer Time: 11:39) zone. So, if you have such a structure, if you have only columnar

zone till the central area you might have cracks because that area is a relatively pore in every respect. The strength is less segregate because of high segregation. So, segregation will be there strength is also less toughness is less. So, that particular region will have cracks will have a lot of segregation. So, centre line segregation will be there.

So, I have mentioned about the location and direction of cracks, this cracks are after all forming because with the strain in the solid shell exceeds the critical limit so that is what we have to remember. If during continuous casting we have less amount of strain on the solid shell you know probability of crack formation is less possibility of formation of crack will be low. So, relatively the cast product will have good quality it will be free from cracks, but if the strain, strain can come as I have told you because a many factors whenever there is solidification towards the end of solidification is a brittle temperature region. So, whenever any strain is there you know the shell is getting bend there will be strand, during shrinkage there will be strain, the ferrostatic pressure will create some strain. So, a different type of strain pos possibility of different type of strain is actually there during continuous casting.

So, if the strains can be controlled within limits then you can have a caster or cast product which have less cracks or no cracks at all. So, the whole idea is to control the strain formation, to control them within limits should not exceed the critical limit then only we will have less cracks.

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Now let us see what are the type of cracks we can form this is very important I will try to indicate what are the surface defects, internal defects for billet bloom and round and also for the slab which is relatively flat. So, just see what are the types of cracks this is a you can call it a billet or a bloom and if it is a round section, then you have a we call it a round. But anyway let us see what are the types of possibilities of location of you know cracks see one we have told it this is a longitudinal mid face cracks what is the location of the crack is longitudinal because in the casting direction and the long direction. So, it is longitudinal, but the location is mid face this is one face this we call it a broad face.

So, here you have a at the mid face at the mid region of the face if you have a crack, we call it and longitudinal crack to longitudinal mid face crack. Now you can have other locations also. So, they are called longitudinal surface cracks this two it can be quite long, it can be even small dimensions can be different, but from the location if they are not in the mid face region you will call it normal surface cracks is the mid face region we call it mid face crack.

Now, this 3 look at the 3 what is there this 3. If there is a crack along this corner this is one corner this is one corner. So, this is also one corner this crack formation has taken place along the corner. So, direction is longitudinal. So, three is basically longitudinal corner crack. So, this is direction is longitudinal, but along the longitudinal corner. So, from the location you can tell it is longitudinal corner crack now look at this crack 4 this is not exactly at the corner, but it is slightly off from the corner. So, we call it longitudinal off crack again the direction is longitudinal, but we call it this one and this one we call it longitudinal off corner crack.

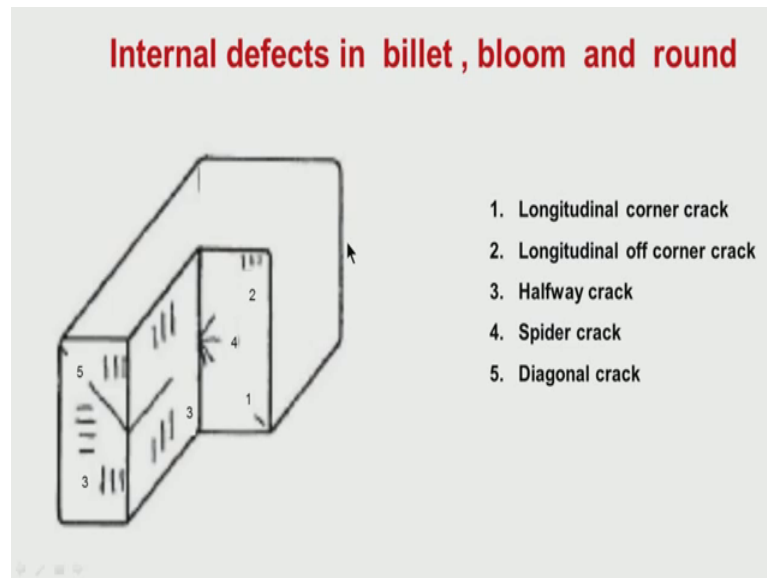
Now, look at 5 what are the direction of this cracks you want was longitudinal five is transverse because it is at perpendicular at ninety degree to the longitudinal direction this is the direction transverse direction this is the direction of the casting, the long direction that is that is called the long direction. So, this is the transverse direction. So, 5 we call it transverse surface cracks surface, but at transverse direction. So, we call it transverse surface cracks.

Look at 6 these cracks these are transverse direction, this you know three was a longitudinal corner crack, but what about those tracks at 6 these are transverse cracks, but at the corner. So, we call them transverse corner cracks. So, depending on the

location, depending on the direction we call them longitudinal or transverse or mid face middle of the face we call them mid face, if it is random we may call it normal surface cracks and if at the corner region, we can it can be direction is long, long in the longitudinal region longitudinal corner crack, if the direction is transverse we call them at the corner region, we call them transverse corner crack this location four local location four here and here are there off corner crack not exactly at the corner, but slightly off from the corner, but not mid face mid face would have been here like 5. So, this 4 is called longitudinal off corner crack.

And there may be some fine cracks anywhere on the surface. So, we call them simplifying cracks. This we call it fine cracks on the surface sometimes these cracks are associated with what I had told you know brittleness at intergranular brittleness for austenite grain boundaries. If you analyze these areas some of this fine cracks may be found around the austenite grain boundaries and the austenite grain boundaries then because of nitrite formation, aluminium nitride, benedium nitride or other types other micro benedium nitrides. So, they can cause such type of fine cracks. So, I have try to explain on the surface of billets bloom and rounds what are the type of different cracks.

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Now, let us see what are the internal defects internal cracks or other defects in billet bloom and round. Earlier I have shown surface defects now let us concentrate on internal defects. What are what are internal defects? Defects which you cannot see on the surface

you can see only at the cross section. So, we have to take a cross section whether this cross section or this longitudinal section then only you can see those defects. Now let us see what are those defects.

So, one is basically what you are seeing only the section of the crack you are not seeing the whole crack. So, the crack may extend this. So, when you are at the interface at the cross section you are seeing only truss of it. So, this is longitudinal corner crack this is near the corner area, this is one corner and this indicates if you cut if you take another section somewhere slightly away from it, if you find truss similar truss; that means, it is extending from here to here. You are seeing only the truss of it in the longitudinal in the transverse section. So, this is called longitudinal corner crack; why longitudinal? Because it is along this directions so, longitudinal and near the corner, so, longitudinal corner crack, but this is internal crack longitudinal corner crack internal crack not the surface crack. Surface crack had it been longitudinal corner crack at the surface you would have found it here the surface, but it is internal crack not at the surface slightly interior, but the location is interior that is why it is called internal crack, but it is longitudinal in direction. So, near the corner, longitudinal corner internal crack.

Now, look at another crack. So, here it is two is called longitudinal off corner crack this is the corner this was the corner. So, one was near the corner. So, it is call it corner crack two slightly away from the corner. So, we call it off corner crack and we are seeing only the truss of it. So, basically this cracks will start here (Refer Time: 21:54) may be going to at this side. So, if you take a section another section parallel to this, if you find the tress of it then; that means, that crack has extended from here to there in that area. So, this is problem over inter cracks you have take look at several sections several transverse sections, then if you just look at one section may be you may miss the internal cracks we have to see several sections several cross sections, then only you will know for that cracks or defects are there at internal locations.

Now, look at this crack that free location what are this cracks? We call them halfway internal crack all these are internal cracks only this is not on the surface. So, internal crack, but half way; that means, from the surface and it is not at the centre event. So, it is halfway between the surface and the centre. I am talking of the in cross section this is the centre of the section this is the surface. So, these are halfway either this or this why do they form? They will normally we will find they we will normally form have the inter

columnar weak areas hot area you can call it, but the strain was such because of the strain maybe during bending or during a non bending, there might be stress formation too much of stress and in certain areas location of the you know shells or refining shell.

So, they are cracks we will generate. So, the strain amplitude value was more than the critical level. So, that is why crack formation has taken place (Refer Time: 23:50) has taken place. So, we call it halfway crack because of his location. Now look at 4, it is a we call it a spider crack, spider crack and where the surface as well as can be internal, but the location it is oriented in different you know small in dimension and oriented in different direction. So, you see call a spider sort of you know it is not a particular orientation is not there that is why it is called a spider like in spider. So, it is an internal crack, but spider we call it a spider crack because of the orientation different orientation it has.

Then we may have a diagonal crack look at 5, what is this this is a diagonal of the and that section of the cast why it can form? I have mentioned the solidification front is starting from here solidification front is starting from here solidification front is starting from this side. So, at the diagonal there is a mismatch of the solidification front columnar grains are exceed the starting from here and extending columnar grains are starting from here and extending. So, at the diagonal the two columns are possibly meeting. So, this is a defect area. So, we call them at the crack formation is at that diagonal area we called them diagonal crack in diagonal internal crack.

Now, what is not mentioned here is another crack here is look at here, this is the central region of the trust you may have a crack here. So, if you see the cross section you may have a crack at the central region you may have a crack on this section. So, this is called a central crack or central defect; that means, if we have too much of segregation then also it will look like a crack. So, you may have a crack you may have a segregation at the central region. So, it is called a central crack or central defect. So, what are the types of internal defects I have talked about longitudinal corner crack one longitudinal cracks you are only saying that tress on a one section, if you take another section you will find tress of it if it exceeds it is a longitudinal direction exceeding and direction longitudinal direction, but internal not at the surface.

So, it is longitudinal corner crack internal corner crack and that. Now we can have longitudinal off corner crack is two I have told you not exactly at the corner region slightly away from the corner, but it is longitudinal. If you take another section you will find stress of it. So, it is longitudinal of corner crack then we have mentioned about the half a crack this three this is half way crack half way crack. So, half way means half way between the surface and the centre we may have cracks. So, is called half way cracks then we may have a spider crack, not any particular orientation different type of orientation. So, it is called a spider crack what a internal crack.

We may have diagonal internal crack at the diagonal areas around the diagonals, but the solidification fronts are meeting. So, it is a weak area in the cast product. So, because orientation is different here, here orientation is particular orientation you know construct you know columns columnar zone is increasing from here to here and this along this face it will be increase this face. So, they are meeting in the diagonal area. So, this is a defect area. So, you can have a crack at these defect areas. So, diagonal internal crack, then I have mentioned you can have a crack at the central location. So, it is called it is central line crack or central crack or central segregation or central line segregation. So, these are the internal cracks earlier I have mentioned about the surface cracks, now I am talking about the internal defects in billet bloom and round.