Steel Quality Role of Secondary Refining and Continuous Casting

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Module – 08
Lecture – 45
Grade - Specific Casting Parameters: Part I

The last session I had discussed about the location and the direction of the cracks in the cast products. So, how the defects we will look like whether on the surface or internal I had mentioned about those. So, there are two basic you know categories one of the surface crack, which we can see on the surface itself for the cast product, where it is bloom or billet or round or slab.

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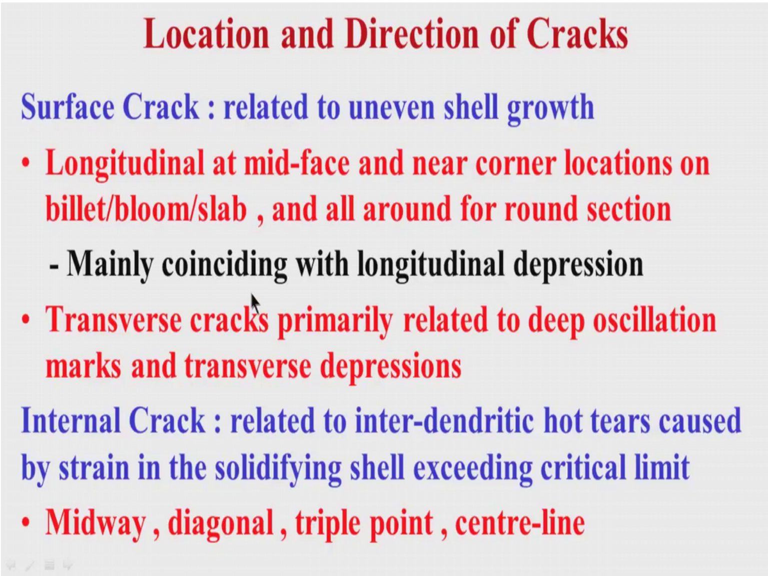

So, there maybe longitudinal cracks and the direction of the casting, which is called longitudinal at mid face or near corner locations or any random locations, and for a round section it can be all around; that means, it does not have any specific location it is round section, but for billet bloom and slab it can be near the corner, it can be off corner it can be mid face or it can be any other locations specific locations.

So, mainly they coinciding with the longitudinal depression, without depression also there might be cracks if there are you know some severe casting problem during the process of continuous casting then also there can be cracks without having any depression. But normally you have surface cracks coinciding we will longitudinal depression or you might have cracks, you might have depression or the cracks will be at the sub subsurface location. I showed one example in the last you know session, now there can be transverse cracks also this why I am talking of longitudinal cracks surface cracks, then there can be transverse cracks primarily related to by the deep oscillation marks or transverse depressions, and I have mentioned that normal oscillation marks which are not deep which are shallow you they do not constitute any defect they are normal you know surface some manifestation of oscillation on the surface.

But if they are deep if the oscillation marks are deep, then this is a matter of concern you have to be careful about avoiding deep oscillation marks. So, if you have deep oscillation marks then sometimes when it goes deep oscillation marks there can be transverse cracks and if they are transverse depressions, there also can be transverse cracks just below those depressions. So, at the surface there can be different defects, there can be different quality issues. Similarly there can be internal defects or internal cracks or segregation which you cannot see with your normal eye because it is not on the surface, but either it is sub surface subsurface what are the different depth, maybe subsurface maybe mid at the mid area; that means, call the central area or maybe you know in between the central area and the surface.

So, it can be anywhere. So, as I was telling if it is mid way midway means at the in between the surface and the central region, it can be the diagonal you know areas; that means, when the two solidification fronts are matching those areas that interface between the two solidification fronts is the weak point weak area weak joint. So, there might be cracks, at the triple point again three solidification fronts are meeting at triple point from the two broad surfaces top and below and also from the one narrow surface. So, all the three solidification fronts are meeting. So, a triple point. So, that is a again a weak area weak joint. So, there might be some cracks and of course, there might be cracks or segregation at the centre line, I have mentioned how this can be controlled centre line defects segregation or you know cracks you know shrinkage cracks or you know too much of porosities can be controlled to some extent by using mechanical soft reduction. I had also mentioned it has to be of certain intensity intensity of reduction and also the location where you put the you know reduction that is very important, it cannot be just anywhere it has to be near the solidfi end of solidification zone.

Final solidification when it is taking place in that area only you have to put pressure some soft reduction, some reduction in thickness through that only you are applying pressure and it is not sudden slowly in steps you are increased there is a gradient of pressure development at the final solidification front. In that process you can reduce the intensity of defect at the central line whether it is cracks.

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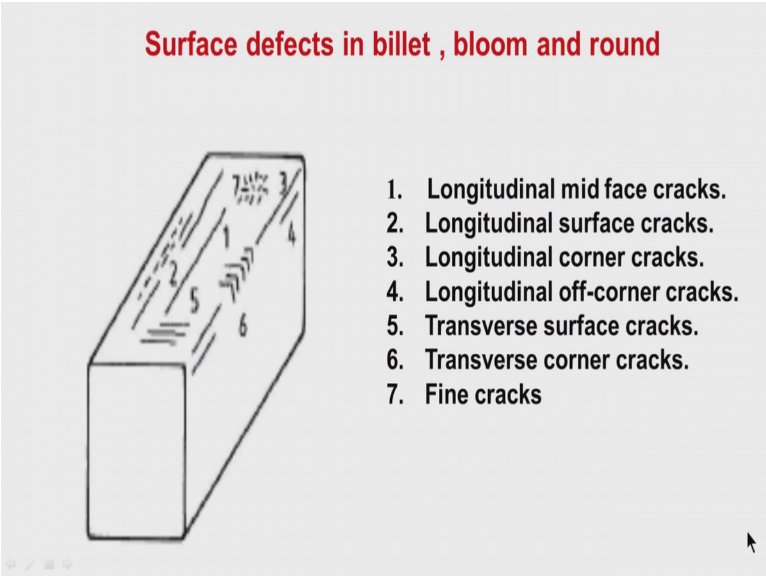

So, whether it is you know prominent segregation pronoun segregation and a centerline. So, and then I had mentioned you know how the different tracks look like at the surface, is billet bloom and round longitudinal you know it can be mid face.

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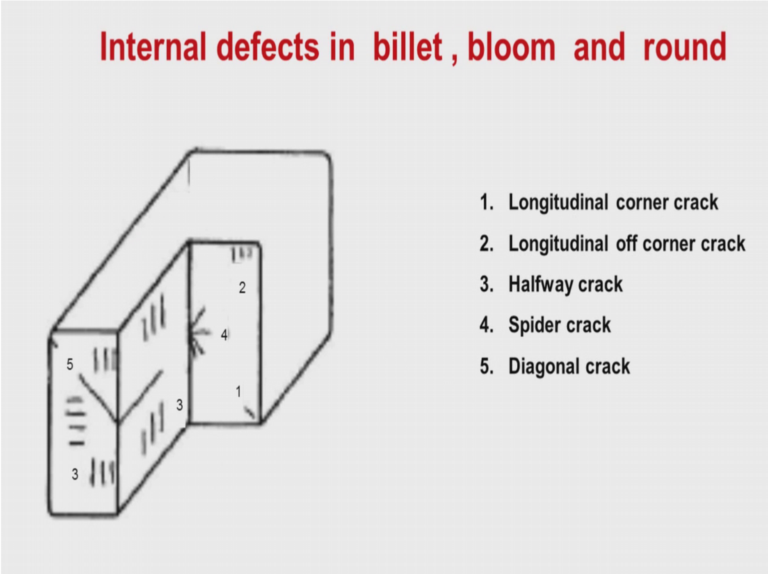

Then I have talked about internal defects in billet bloom and round how do they look like and you have to cut and cross section, we have to see only at the cross section the surface you do not say anything. These are internal defects surface is absolutely free, but if you look at the interface cross section then will you will be fine some defects. If they are present it can be diagonal it can be you know at them mid area it can be near the corner, it can be you know this is corner this is half corner and this is spider of different orientation.

So, similarly on the cast lab also, you may have on the surface lots of cracks.

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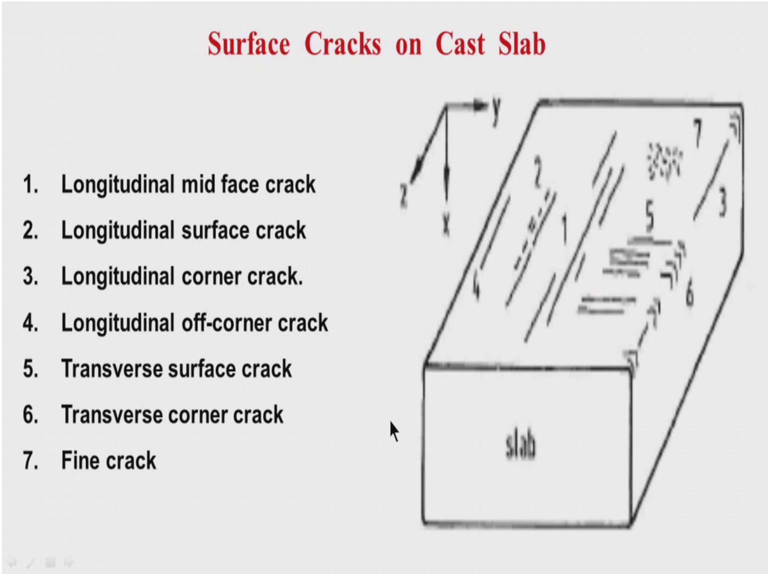

And different orientations longitudinal mid face near the corner at the corner and transverse at the corner all sorts of you know, this is fine cracks without having any typical orientation, but maybe small cracks located at certain areas.

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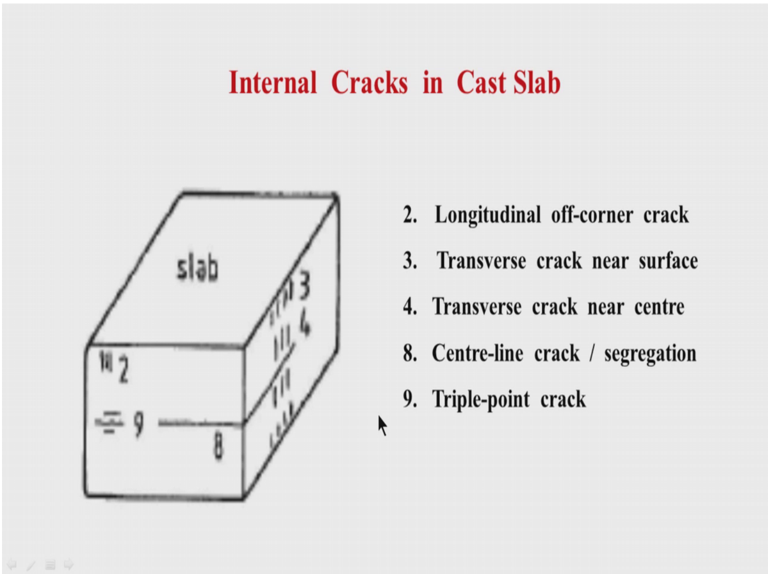

So, again and the slab interior the internal cracks you might see this is a centerline crack or segregation. This is a triple point this is a triple point solidification front moving from here solidification moving from the broad faces, meeting at the you know triple point area. So, this area is very weak. So, you might have crack development at those triple point areas. Then this is half corner longitudinal you are looking only at the tress on the section you are looking at the tress of the crack, then again it can be transverse crack near the surface transverse crack you know near the centre.

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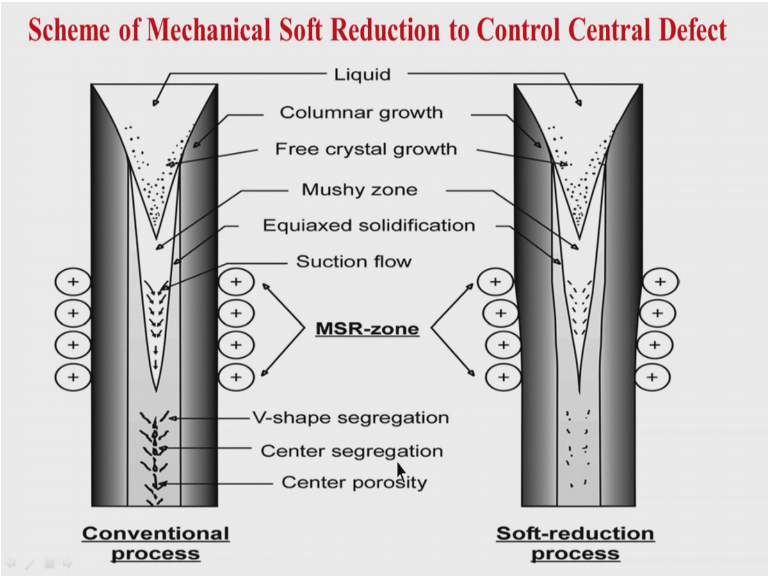

So, also source of cracks I have talked about you know scheme from mechanical soft reduction to control defect at the centre line, I have mentioned two important you know issues here where you put the pressure.

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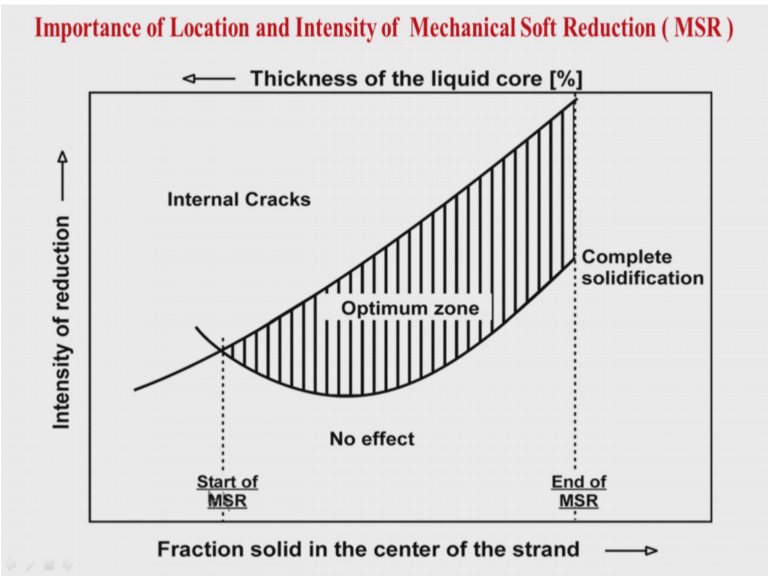

And how much pressure you put this is very important where you put the pressure, you put the pressure near the solidification competition zone and if you put less pressure it will have no effect, if you put more pressure there might be formation of internal cracks. So, the intensity of reduction in centre of pressure has to be some not optimum. So, this is again important issue.

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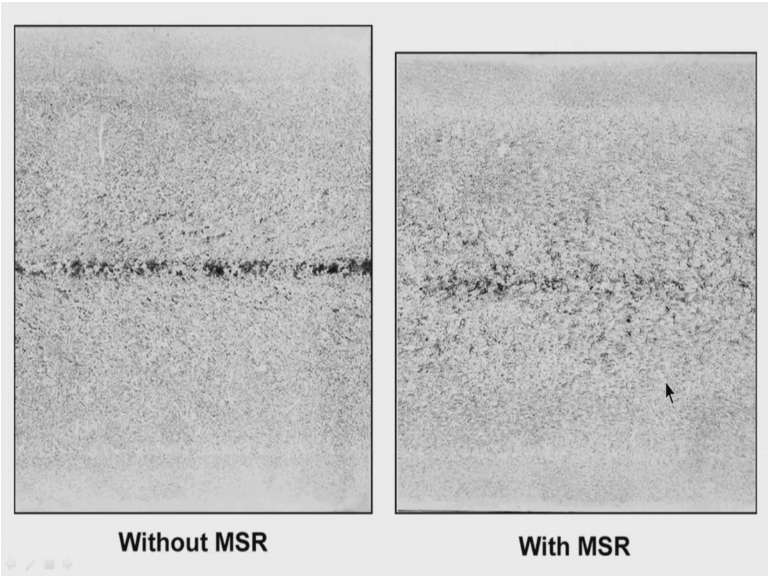

Then how with mechanical soft reduction the intensity of you know central defect, central crack or central segregation is coming down this is just to show.

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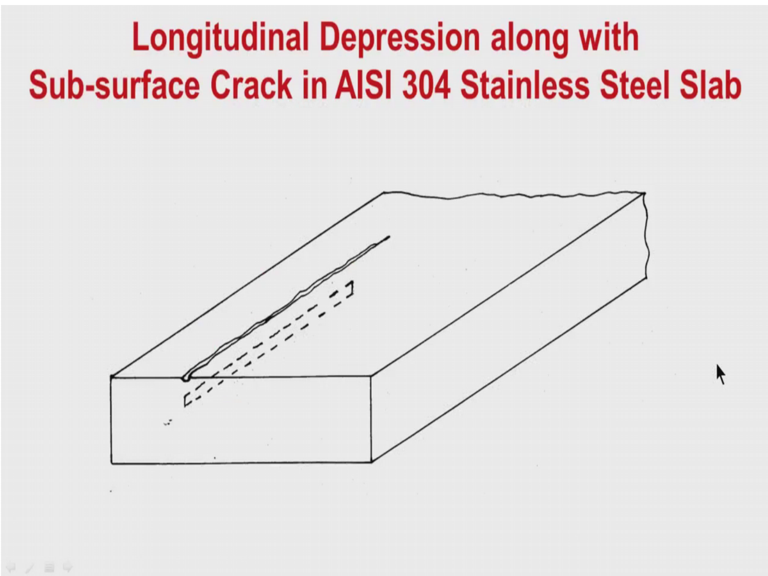

Then I talked about you know in three zero four is a typical so called peritectic grade in stainless family.

So, under the you know depression longitudinal depression, you might have sub surface crack on the surface you are saying only depression, but if you take a cross sectional view you will find trace of subsurface crack. So, how it can be taken care of by minor adjustment of chemistry how by taking a nickel equivalent of chromium equivalent slightly less than the peritectic you know start chemistry which is 0.55.

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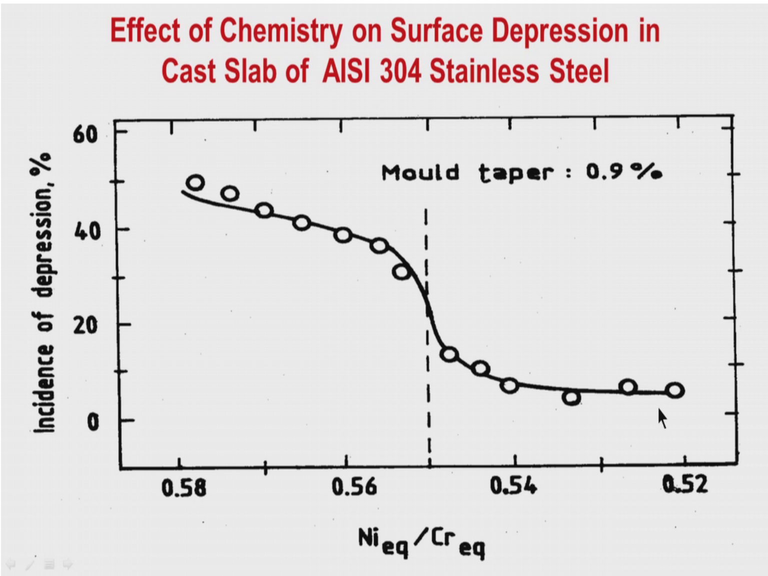

So, if you nickel equivalent by chromium equivalent is say 0.54, 0.53, 0.52 the incidence of depression is much less compared to the situation when this nickel equivalent by chromium equivalent is more than 0.55, it is about say 0.58, 0.57, 0.56.

So, by minor adjustment of chemistry of course, within the range of specification if I say three 04, it is possible to control the incidence of depression to large extent. Keeping the parameters more or less casting parameters like mould taper more or less.

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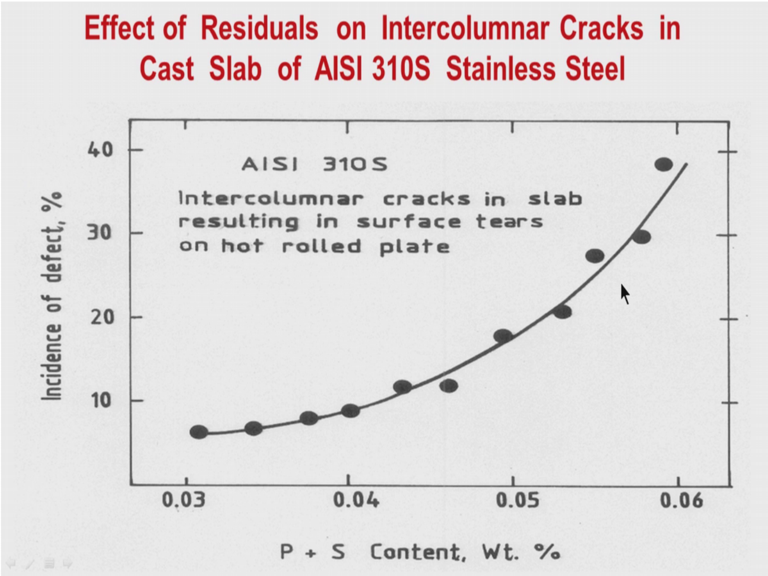

Similar then I have mentioned for a austenitic solidification situation, like AISI 310S which is a totally austenitic grade at all temperatures. If at start off solidification it is austenite during solidification it is austenite, after solidification it is austenite, and continues to be austenite, in such grades micro segregation is relatively more because of austenitic solidification. So, here the issue is to control of phosphorus sulphur assumes much importance. The first for as an sulphur have to be controlled to you know reduce the incidence of inter columnar cracks in slab this inter columnar cracks, it always do not see in the surface it is internal locations at inter columnar you know locations.

When this cracks in slab we will finally, result in the role product you know we call it surface tears; that means, surface cracks on hot rolled plate or you know hot rolled coil or (Refer Time: 10:41). So, we have to be careful about the inter columnar cracks and the solution lies in controlling phosphorous for saulphur.

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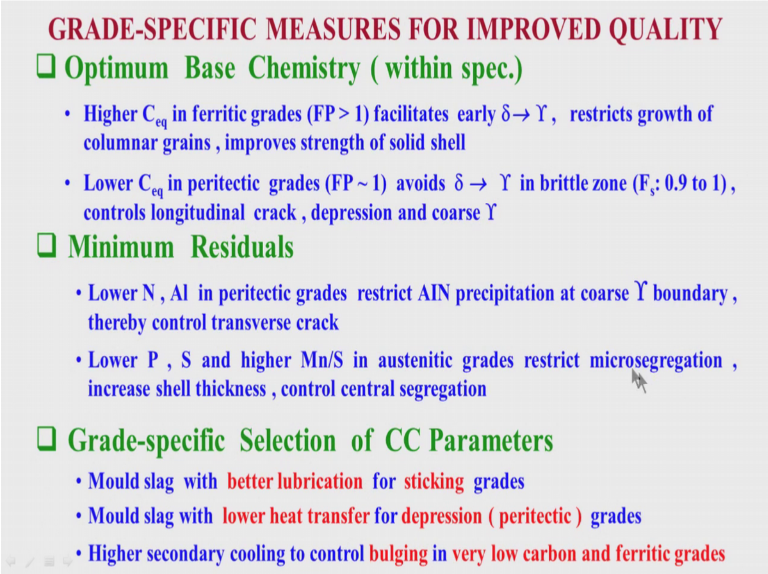

So, now, today I will talk about when we understand, what is the solidification characteristics whether it is a you know ferritic solidification or austenitic solidification, whether it is characteristic is taking type or bulging type on the one and all it can be depression type, on the other hand then what do you do what is the way out. If when you know the mode of solidification when you know the solidification characteristics, then we know I have told you we can adjust the casting parameters accordingly.

So, that the solidification quality; that means, the quality of the cast product is relatively better. If you understand how the solidification is taking place whether it is through delta or it is through gamma or when the delta to gamma is taking place this transformation the you know at what temperature is taking place, at what stage is taking place is it taking place at the start of the solidification or towards the end of the solidification which is very crucial which is very critical. So, let me careful about that or it is taking place after solidification. Like you know when your ferritic grade like very low carbon or a silicon steel you know is a very much ferritic solidification you have to delta solidification delta ferritic solidification, and delta to gamma takes place only at much lower temperature

So, they are what are the issues? Number one when you have a you know. So, called peritectic grade, then what are the issues? Issues there is it is taking place through initial solidification is taking place through delta, but delta to gamma is taking place transformation is taking place towards the end of solidification which is a brittle temperature region. So, that has certain defects, surfex surface you have lot of depressions you may have crack because of that. So, it is a depression prone grid, then you might have a chemistry like very high carbon say more than 0.3 .35 or more than 0.5 or a in stainless steel family a grade like 310 or 310S, which is totally austenite is solidification they are what happens? During solidification the shell is thin because of pronounced micro segregation of phosphorus sulphur and other elements.

So, here if you understand how the solidification is taking place, whether it is a depression prone grade or sticking or bulging prone grade, accordingly we have to decide the casting parameters. So, first let us talking of this grade specific selection of casting parameters; how do you do like I have mentioned for the sticking grades the you know the important parameter there is lubrication. It has to have better lubrication in the mould so that, the sticking situation can be taken care of. So, that the friction going to sticking does not go beyond a certain value critical value. So, their lubrication has to be better for the sticking grades. So, accordingly the mould slag has to be suitably selected the characteristics of the moulds like should be such that it has better lubrication.

So, that the sticking tendency can be controlled; if there is too much of sticking their might be sticking break out the surface may be you know ruptured. So, all sort sub problems will be there. So, if you understand the solidification characteristics we know the it is a sticking grade, for say very low you know carbon or you know ferritic grades like 430 or may be silicon steel, there are all very prone to sticking and be not and be need the mould below the mould it is it will indicate bulging. So, they are also something has to be done, as I have mentioned secondary cooling has to be high to control bulging in very low carbon and ferritic grades, silicon steel which is of ferritic grade ferritic stainless steel 430. So, they are secondary cooling intensity what should be distribution these will play a very important role, and the mould slag has to be such that you get better lubrication.

But for a peritectic grade like say point one percent carbon or in the stainless steel family 304 grade, which indicates depression. So, it is at grade which shows lot of surface depression. So, what we have to do why they are lot of surface depression, because this delta to gamma transformation taking place, at the crucial brittle zone of between LIT and solidification completion; that means, between the solidification zone of 90 percent and 100 percent on the solid fraction it is between 90 percent and 100 percent if the delta to gamma transformation takes place in that area which is a brittle temperature zone, you have additional you know shrinkage; that means, additional strain. So, there is a possibility of crack formation depression formation. So, what do you do for such grades for such grades? You control the heat transferred in the mould; because the everything is taking place in the mould surface solidification is taking place surface sub surface solidification is taking place in the mould, maybe about 10, 12 or 15 millimeter is already cast in the mould.

So, whatever control you have to do have you have to do a control in the mould by using mould slag which has characteristics of low heat transfer mould slag should be such that the heat transfer is low and it is uniform throughout the periphery of the mould; that means, addition of powder is very important you should always have a uniform powder addition, throughout the periphery of the mould sometimes you know certain area certain localized areas of the mould might have higher powder, higher amount of powder or might have less amount of powder and because of that heat transfer near the periphery near the meniscus in the mould gets affected. So, first it has to be uniform powder distribution, uniform you know feeding of powder from the top and also the powder characteristics should be such that we have lower heat transfer, we have uniform heat transfer and therefore, we have less of depression on in this peritectic grades.

So, first depending upon understanding the solidification characteristics, understanding whether it is a sticking and bulging or depression grade, we have to select the casting parameters accordingly. Then I have talked about you know base chemistry what should be the optimum base chemistry within specification this is very important. All steel grades have a specification which is designed based on the application requirement, but there is a range for all the alloying elements. So, within the specification range it is always possible to do minor adjustment of chemistry, and I have given you an example how minor adjustment of chemistry can give much better quality, I have talked about AISI 304 stainless steel where normally the 304 chemistry gives an nickel equivalent or chromium equivalent is around 0.57 I am talking of the normal yeah which people use.

But the range of chemistry such that minor with minor adjustment, you have steel in 304. So, what can be done? Because this 0.55 is the start of the peritectic temperature a peritectic you know reaction in the stainless steel family which is at 0.55 nickel equivalent by chromium equivalent I have discussed this earlier. So, if you can adjust the nickel equivalent by chromium equivalent slightly lower value say 0.54 0.53 0.52 then you can get much less depression why this is happening? Because this I have talked to about you does it delta to gamma transformation for this types of chemistry whether it is around 0.1 or and 304 stainless steel 0.1 percent carbon grade or AISI 304 stainless steel,

It takes place around the solidification completion temperature and I have told told you that solidification end region say from 0.9 percent solidus, it has at 0.9 solid fraction to complete solidification; that means, when the solid fraction is 90 percent 200 percent, that area is very prone to depression formation because it is a brittle temperature radian. It is a temperature area between LIT and ZDTE; that means, when the you know ductility of the or the you know the reduction in area of the strand solid shell is very low almost 0 and then if you have shrinkage due to transformation of delta to gamma that creates crack formation and depression. So, what we are doing we are slightly adjusting the chemistry to bring it you know lower than the peritectic start temperature.

So, what is the issue here delta to gamma we will take place lower than solidification at temperature which is lower than solidification completion not around solidification completion. So, with minor adjustment we can you see we can get incident very low incidence of this depression in, this depression prone grade of 30 for stainless steel or so, called 0.1 percent carbon, which is a peritetcic which is known as a peritectic chemistry and then I have also mentioned about 310S it is a totally austenitic solidification grade. So, here what happens due to total austenitic solidification? The role of micro segregation is very pronounces and because of that the shell is very thin and because of that you know the shell cannot with stand ferrostatic pressure. So, you have lot of inter columnar might have lot of inter columnar cracks, you know that those area is having low strength inter columnar areas are very reach in segregating elements like phosphorus sulphur and there you know in (Refer Time: 22:21) fusion problem is there solidification temperature also comes down.

So, this inter columnar cracks incidence of this cracks is very high in a grade like austenite (Refer Time: 22:29) which is a austenitic solidification grade. It is similar to very high carbon grades like you know 0.5, 0.6, 0.7 (Refer Time: 22:38) steel all these grades you have this problem of inter columnar cracks. So, we have to be careful how we can be careful the only success can be if you reduce the phosphorus and sulphur contact then the incidence of segregation will be less and then inter columnar areas will be relatively less sensitive through to crack formation. So, the incidence of cracks or less and if the if the incidence of cracks or less then when you roll it the surface of the role product also we will indicate less surface steel less surface cracks. So, here the internal cracks is the main issue. So, if you understand what is the solidification characteristics, accordingly we can device the solution route what should be the way out how to take care of the problem. So, for austenitic grades of solidification I have mentioned phosphorus and sulphur is very important, manganese by sulphur issue is very important. So, that is precisely what we have to do.