Steel Quality Role of Secondary Refining and Continuous Casting
Dr. Santanu Kr Ray
Department of Mechanical Engineering
Indian Institute of Technology, Madras

Module – 08
Lecture – 44
Remedial Measures to Control Defects: Part III

Hi, welcome to another defect for another type of stainless steel AISI 310S, I have mentioned you mention to you that this particular grade is having austenitic solidification like high carbonic equivalent; you have austenitic solidification beyond sub 0.5.

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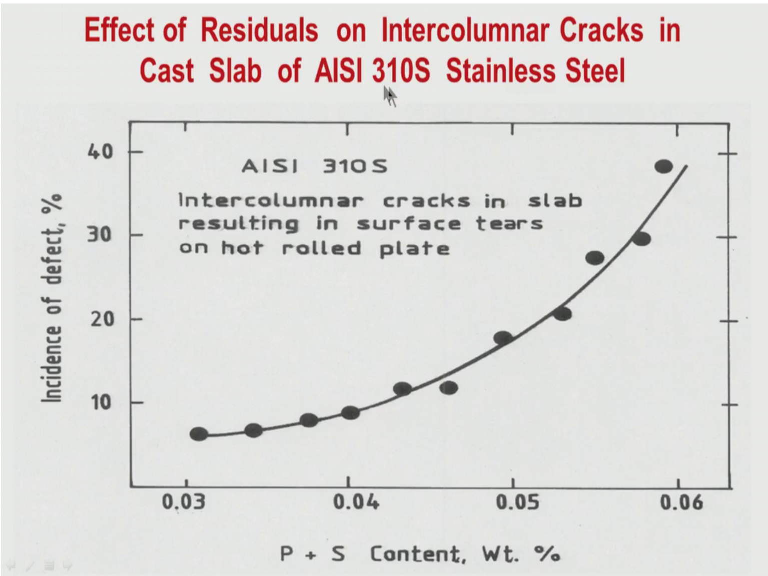

We have only austenitic solidification similar is the case for a 310S; you know for the nickel equivalent or chromium equivalent above up 0.74, between 0.55 and 0.7 you have peritectic range. Above up 0.74 you have totally austenitic solidification; that means, you have initially liquid than liquid plus austenite and finally, austenite when it is solidified no other transformation.

So, what is the speculative for such grades I have mentioned, since this is austenitic solidification incidence of micro segregation is quite high, I have given you the figures earlier that between delta solidification and austenitic solidification, incidence of micro segregation for austenitic solidification is relatively high for the deleterious elements like phosphorus and sulfur. I have given you figures earlier for austenitic solidification it is relatively less this values of k; values less means you have more segregation. So, if you have more segregation what is the problem? Problem is to fast the interdendritic regions are more rich in all this elements phosphorus sulfur and other alloying elements, that is number one.

So, the interdendritic areas are relatively weak because of too much of segregation number 1. Number 2 because segregation is more the solidus completion temperature; that means, the final solidus temperature actual solidus temperature when the solidification is complete is also depressed or it is coming down. So, mushy zone is increasing. So, during solidification the shell thickness solid shell thickness is less and the mushy zone is quite deep and wide. So, what is the implication of that? Implication is there can be lot of sticking tendency, there can be lot of because of this the shell is thin and the shell cannot withstand the pressure whatever you know pressure will be generated due to you know due to may be ferrostatic pressure or due to mechanical strain whatever is there. So, there will be lot of possibility of formation of cracks inter columnar cracks in slab.

This inter columnar cracks in slab when you are finally, inter columnar cracks means these are internal cracks, you may not always see them on the surface. But this internal of cracks I have told you slab may have lot of internal cracks because of internal because of weak inter columnar areas this is particularly too too for high you know nickel equivalent by chromium equivalent situation a grade like 310S or a chemistry like more than 0.5 percent carbon, where it is totally austenitic solidification the shell is very thin during solidification. So, the chance of lot of crack formation in the shell because it is thin it is relatively weak. So, this inter columnar cracks in the inter columnar (Refer Time: 03:57) finally, when you are rolling the slab they will come to the surface and you get surface tears we call it in a hot roll plate not slab.

So, this 310 slabs have been rolled to plates and it has been found that there were lot of surface tears; that means, surface cracks may be find or may be slightly deep cracks slightly longer cracks. So, these are basically originating from the internal inter columnar cracks in slab, which are existing in slab sub surface or you know at the interior of the slab interior locations of the slab, which are coming to the surface during roll hot rolling. So, what has to be done? As I have mentioned this basically happening due to micro segregation so, austenite solidification. So, the solution lies in controlling the amount of phosphorus and sulfur that is what we have done. So, you see when the phosphorus and sulfur content is relatively more.

So, 06 the incidence of such defect is very high is about 40 percent 35 percent 40 percent and if you can bring this phosphorus or sulfur to as low as 03, you see the incidence has come down to less than 10 percent.

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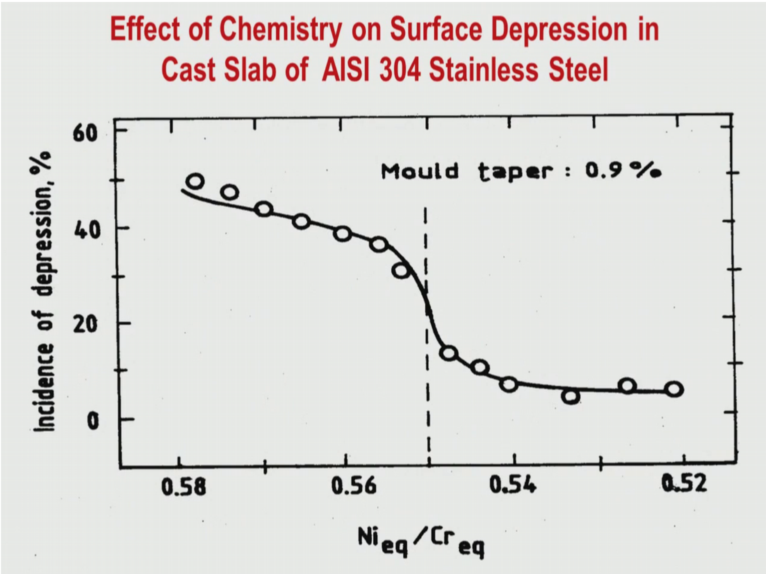

So, depending on what is the type of defect. What is the alloy the solution has to be accordingly decided and 304 depression type of grade we adjusted the chemistry by controlling nickel equivalent by chromium equivalent bringing down it from slightly higher than 0.55 to less than 0.55 and we got much improvement in as for as the incident of depression is concerned. For 310S it is austenitic solidification different from 304 totally different on a sequence of solidification.

Here the problem is inter columnar cracks which are located internal in the slab. 304 more problem was surface depression and because of the surface depression there was surface cracks. Here the problem was internal cracks at inter columnar locations in slab, they are giving raise to or resulting in surface tears in the hot rolled plate whatever has been done from slabs. So, here the since it is a totally austenitic solidification we have to control or rather reducing intensity of the defect by controlling phosphorus and sulfur which are notorious elements as for as segregation is concern, micro segregation is concern.

So, the solution lies in controlling the phosphorus sulfur you know. So, the control of phosphorus sulfur is more important for austenitic type of solidification as compare to peritectic type of solidification. In peritectic type of solidification this much of control would not resulted in much improvement accept very minor improvement, but here it has a dramatic improvement. So, again I am repeating depending on what is the type of solidification, what is the type of grade you have to decide what is the solution. A typical alloy typical grade will have a particular defect all defects on not identical whether you will be a surface defect, whether it will be internal defect, it may depend on the solidification sequence, it may depend on the chemistry as I have mentioned several times the. So, called peritectic grades it has a particular type of defect defects are more at the surface for such type of grades, more of depression does on the surface because of the depression that may be subsurface cracks, but the problem is depression problem is surface cracks.

So, if we can control those if you can have a better surface, we are successful and having a good quality, but for 310S problem is something else problem is more of internal cracks. So, what have to do? You have to control phosphorus and sulfur. Sulfur you can you can control some again I have to telling you by using a hard ratio of magnesium sulfur more than 25, more than 36, but for phosphorus there is no other elements which can take care of. So, you have to control phosphorus, to get a better quality steel were this type of cracks the incident of this type of cracks are relatively less. So, I have mention to you different type of defects. First I have mentioned about you know the defect and the central region; it can happened you know in all types of grades.

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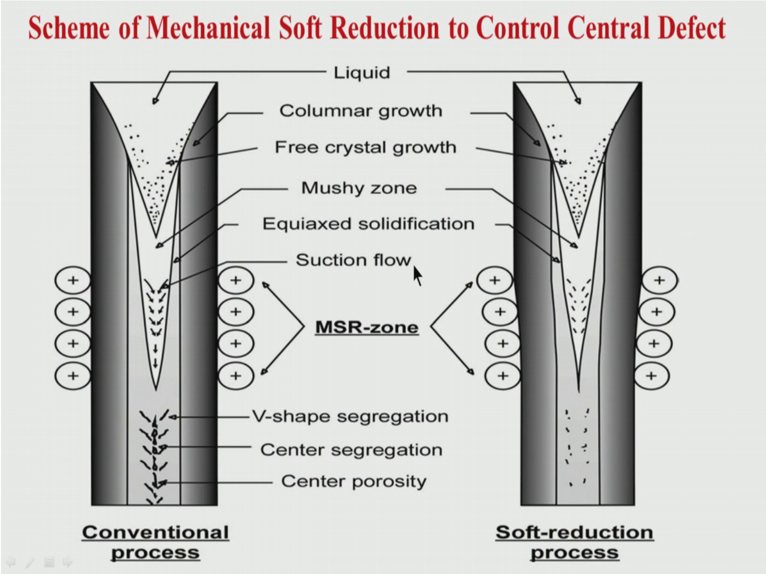

But it will be relatively more for austenitic grade which undergoing austenitic solidification why? Because there micro segregation is relatively more because micro segregation is more, the segregating elements, will get a chance to segregate towards the last stage of solidification. So, this defects are relatively more in slightly higher carbon chemistry will having hard carbon or in stainless steel which were having hand nickel equivalent by chromium equivalent. So, what has to be done there? You have to use mechanical soft reduction to control the central defect. Mechanical sub division I have mentioned two things are very important; were you use the mechanical soft reduction what location and what is the intensity of the soft reduction, how much pressure do you put, how much thickness you reduce so that that creates the pressure it. I have mentioned the two things are important.

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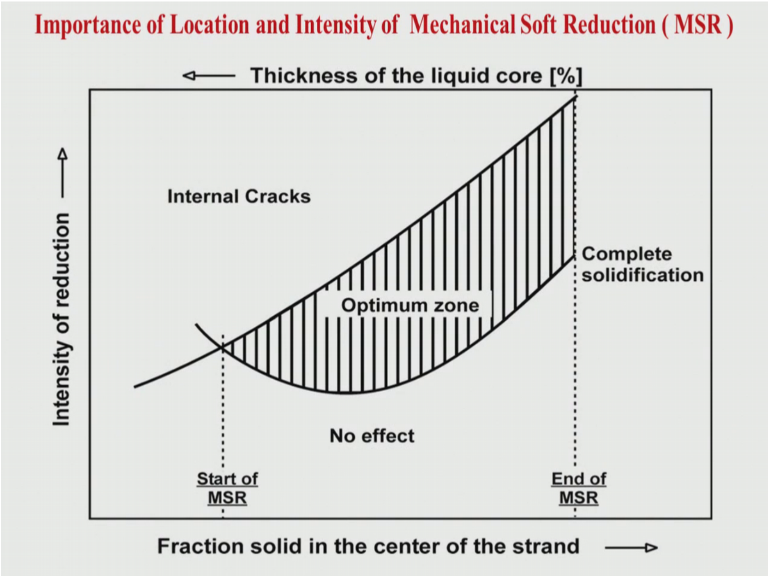

Where you put mechanical soft reduction and how much of intensity of soft reduction you are giving. If you put relatively less amount of pressure, it may not be adequate may be in adequate to compensate the you know shrinkage, formation of shrinkage central shrinkage. So, you have to have adequate amount of reaction, but if it is more more than adequate so, it will be it will create more harm and good, it will generate internal cracks, that is why for any factor there is a optimum range nothing can go beyond that. So, it should not be too low it should not be too high it should be adequate, within the desirable range. So, the location as well as the intensity the amount of reduction is very important to get a good internal quality, where cracks will be less almost nil, segregation amount will be less and will be distributed as I have shown in the figures here.

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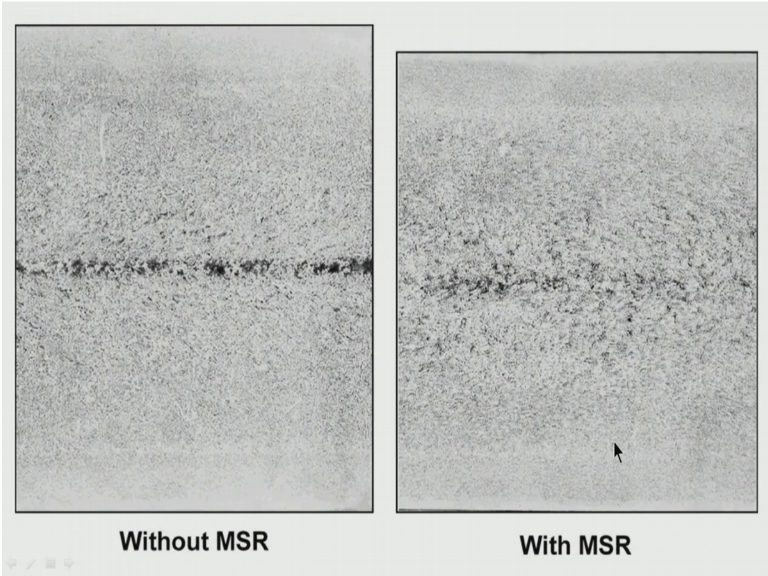

You see there is both crack as well as segregation at the central region and intensity is quite high using you know mechanical soft reduction in the same alloy, same grade, same type of you know continuous casting parameters, same type of caster. Only different was we are using this facility mechanical soft reduction in the caster so; that means, certain areas of the caster where solidification is getting completed, they are we have given mechanical soft reduction by changing the distance between the rolls. Basically how we are giving mechanical soft reduction? We are changing the distance these are the rolls you know. So, we have changing the distance between the rolls or normal distance is this we have slightly decreasing the distance and finally, coming to the desire distance.

So, by in this process we are putting some pressure we are giving some mechanical reduction, but again I am telling it is called soft reduction, it is there is gradients slowly it is increasing not suddenly. If suddenly increase the reduction; that means, you will give a some certain strain which is not desirable. So, the strain rotate is important slowly it should increase, the value should be relatively less how at the rate of increase should be low the strain rate also is important should be relatively less. So, these are important issues which should be kept in mind. So, the central quality can be improved by mechanical soft reduction.

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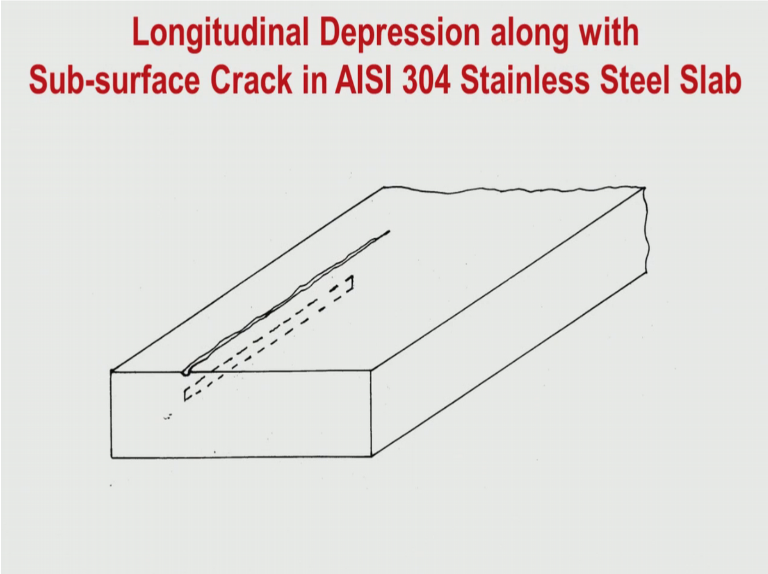

Then the depression in 304 types of you know peritectic grades stainless steel, it can be improved by controlling minor adjustment of chemistry. By having the chemistry which is slightly less than the peritectic start nickel equivalent of chromium by nickel by nickel equivalent divided by chromium equivalent value of 0.555 I have told you, is the peritectic you know start chemistry. So, instead of slightly more than this you should have a slightly less than this nickel equivalent chromium equivalent.

So, then only you can avoid this delta to gamma during solidification, this delta to gamma transformation for this type of chemistry will be having lower than at a temperature which is lower than the solidification complete temperature. So, that delta gamma transformations strain is not present in the crucial brittle temperature region, which is around solidus temperature, this is the strategy which we are following here. By minor adjustment of chemistry delta to gamma transformation we are bringing down from around end of solidus to lower than solidus.

If it is lower than the solidus the crucial brittle temperature range we are avoiding. Crucial brittle temperature range is between solid fraction of 0.9 and 1; between temperature of liquid impenetrable temperature LIT and I have mentioned earlier it was zero ductility temperature ZDTE which coincides with solidification completion temperature. So, if we can have the delta gamma transformation at a temperature lower than you know solidification completion temperature or ZET temperature then the problem is tackle into a large extent. So, this is the strategy we are adopting for 304 type of steel where you have lot of surface depression. Now another type of defect is the inter columnar cracks internal cracks in 310S type of you know stainless steel. Similar cracks will be there for ball bearing type of steel which has a totally austenitic solidification. Similar type of crack we may have for a you know steel which is having 0.5 or 0.6 percent carbon. So, there what strategy we have to follow we have to control phosphorus sulfur and increase the manganese by sulfur issue so that the extent of segregation is less. If the extent of segregation is less the shell thickness relatively more and the interdendritic region will be relatively less impure because of lower relatively less amount of phosphorus and sulfur segregation is less means segregating phosphorus sulfur and other alloying elements will be going to the interdendritic area relatively to a lesser extent

So, in that process you can control the inter columnar cracks. So, the solution lies in controlling phosphorus and sulfur. So, again I am telling you first you have to understand for any grade what is the type of solidification whether it is sticking type characteristic or it has a depression characteristic. Accordingly we have to select the solution we have to select the casting parameters, we have to select possibly the chemistry optimum chemistry range as I have mentioned for you know 4 304 type of grade. I can give some more examples may be later I will give you some more examples, but today I have mentioned three types of defects which can be tackled or brought down by having suitable strategy. 310S grade of steel the problems are inter columnar cracks in slab which result in surface tears surface cracks for hot roll plates or even it can happen for the hot rolled you know I have talking of plate here it can hot roll coils also.

So, for this type of grade solution is something for a 3 0 type of steel the solution is controlling minor adjustment of chemistry, to bring it slightly lower than that nickel equivalent chromium equivalent slightly lower than peritectic start chemistry so, that the delta to gamma does not takes place within solidification range, it takes place lower than the solidification range, and it avoids the so called high temperature brittle temperature zone between LIT and ZET. So, this is the technique which can be utilized. Another I have told talked about how you can control the incidence of central segregation and central porosity, you know for this is may be true for any type of grades, but it is incident is relatively more for sticker type of grades or austenitic solidification grades where you have austenitic solidification and the muchy zone is relatively more, the mushy zone is more this problem is also relatively more.

So, you can control this by having soft reduction I have mentioned here the location of soft reduction has to be properly selected towards the end of the solidification, final stage of solidification and how much of you know soft reduction do you give that is also important. If it is less than adequate value it will have no effect; if it is more than the adequate the optimum value it may generate cracks.

So, the optimum level is very important. So, again I am repeating depending on the type of solidification characteristics, you may have different type of defects whether surface or internal even in internal you can at the center or other locations. So, if you understand what is the solidification sequence, then you can understand why those cracks are forming, what are the problems of those quality or why quality is getting affected and if you understand that you can devise the solution you can devise the way which can take cared of this problem. This is very important for understanding.

Thank you very much.