Steel Quality Role of Secondary Refining and Continuous Casting

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Module – 08
Lecture – 43
Remedial Measures to Control Defects: Part II

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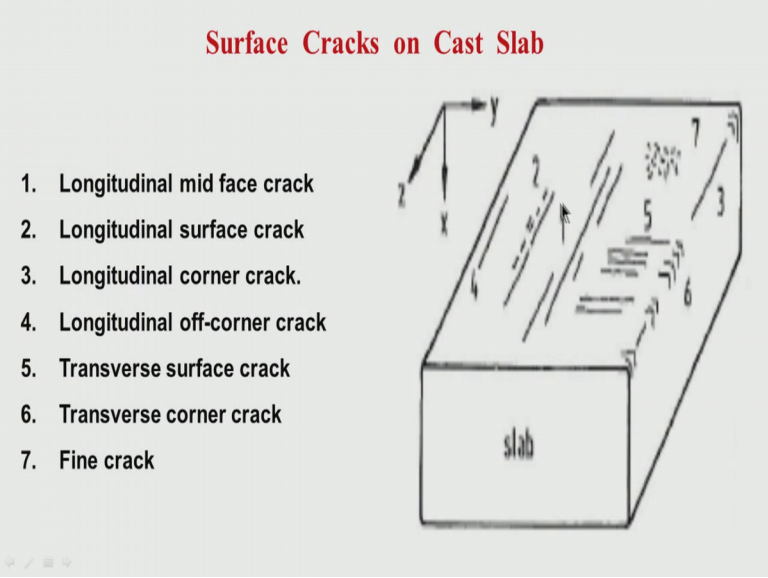

Let us see about this; what is this longitudinal cracks or longitudinal depression at different locations. So, how to take care of this, now I will give you an example of this longitudinal depression how does it look like in actual slab for a stainless steel product we have found out central; central rather a longitudinal depression you see here.

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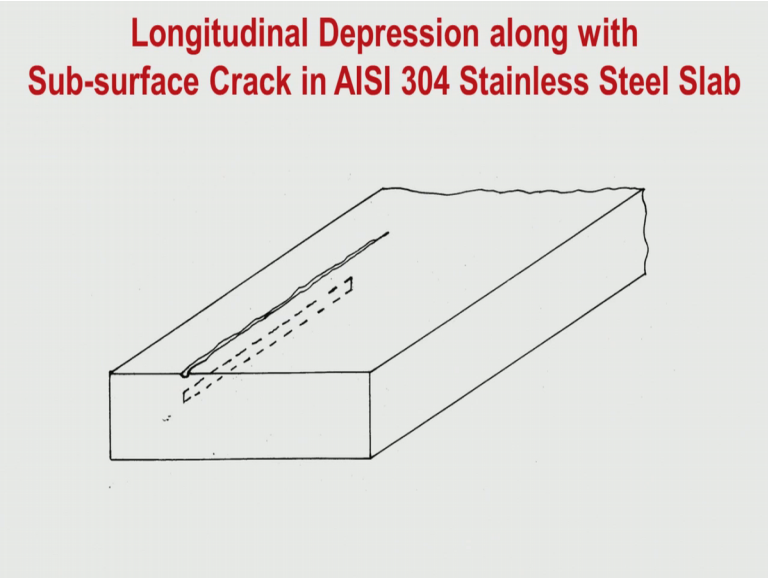

So, this is a slab of AI 304 stainless steel and we have found some depression longitudinal why it is longitudinal because the direction is in the longitudinal direction it was in the direction of the casting.

And what you cannot see first you are seeing the depression, but if you look at the section this section you will find that beneath this depression there are certain cracks sub surface cracks. So, as I was telling you that depressions most of the time they will be associated with subsurface cracks which you may not see, it is under the at the normal you know surface you will just see a depression, but beneath that under that just below that if you look at the cross section this section you will find there is a trace of crack. So, if you again look at the other cell a section, here again you will find the crack it depends how long is the crack. So, you will; you can see its stress at different locations of sections.

So, now it is as I was telling you it is AISI 304 stainless steel and I had mentioned to you earlier that this grade like that typically peritectic grade has problem of depression. So, AISI 304 stainless steel, it is expected to have some depression, unless proper care is taken. So, I will now tell you; what care we will take or we have taken to address. This problem to reduce the intensity of this problem, there will be some depression because it is an intrinsic to this particular grade why depression is forming, I had mentioned earlier there are 2 broad categories of chemistry certain chemistry is a has a characteristic of

sticking and bulging and certain other chemistry has characteristic of depression; what is that characteristic chemistry which will give depression either the chromium equivalent is around point one for you know; carbon steel or for stainless steel you have AISI 304 type of grade where the nickel equivalent by chromium equivalent is going to play an important role because since it dictates the chemistry.

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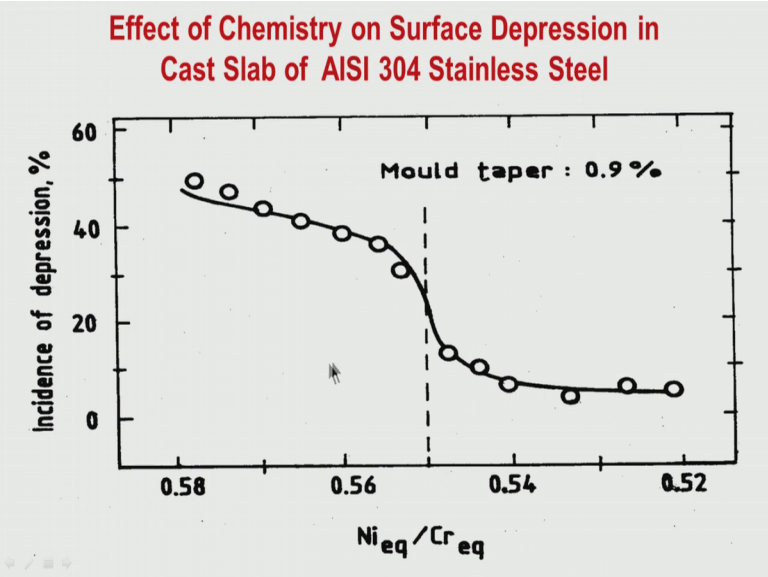

So, now I will show how we are managed to control this problem yeah here what we had showing is what is the incidence of depression; that means, we find out how many depressions are there longitudinal or transverse. Let us talk about longitudinal for the timings because I have shown you the longitudinal yeah depression you can have a; yeah transverse depression also you can have deep oscillation marks also in this type of bread, but let us now concentrate on longitudinal depression along with subsurface crack. Now why this is a problem media because when you will be rolling this material from slab when you are going to a hot rolled coil; what will find is this subsurface cracks will come to the surface and we you have lot of surface defects in the roll product.

So, the defect is basically originating from the cast slab itself though we are finally, getting a crack in the roll product, we had depression on the cast product under the depression below the depression there was subsurface crack which was not visible on the slab surface itself, but after rolling this subsurface cracks will come to the surface and you have surface lamination sort of problem.

So, how do you control it yeah I have mentioned here thus we are keeping the mould taper fixed what is mould taper mould taper is done by giving certain you know tapering to the mould plates, you know slab is basically how the slab mould is there, unlike you know bloom or billet you know or a round you know mould which is a single piece here you are using basically plates. So, brought 2 plates for the broad surface 2 plates for the narrow surfaces, now as I have mentioned that because of solidification there will be some shrinkage.

So, at the top of the mould solidification has not yet started. So, the gap between the 2 broad phases; that means, 2 plates which constitute broad phase there the distance is something say x, when you are coming down of the mould at a mould bottom already some amount of solidification has taken place there is a solid shell thickness, then only you can when its coming out of the mould, it can resist otherwise there will break out you know there will be shell will snap. So, there is some thickness maybe 15 millimeter maybe 20 millimeter maybe 25 millimeter when it is coming out of the mould bottom. So, this shell; that means, solid shell; when it is forming, it will have some shrinkage is it the shrinkage means what it will move away from the mould one. So, the gap at a top of the mould between the 2 plates and gap at the bottom of the mould again 2 plates similar location at the bottom and the top if you compare.

If it was x at the top say the thickness of the slab is 200 millimeter. So, for getting a final thickness of 2 millimeter, you have to back calculate and say you have set you know the at the top of the mould say 200 millimeter will be say about 220 millimeter, I am giving you a rough estimation. So, if the top of the mould the distance is between the 2 broad phases is 220 millimeter at the bottom of the mould, it should not be 220 millimeter. It should be something less than that. So, say it is 215 millimeter. So, what for do we have decreasing by 5 millimeter to accommodate the shrinkage because if it is 220 at the top and 220 at the bottom; what is going to happen because of the shrinkage of the shell there is a gap formation between the mould wall and the shell surface.

So, if there is a gap formation heat transfer will be affected we do not want that. So, to compensate for the solidification shrinkage in mould the thickness or the distance between the 2 mould plates; 2 plates which constitute mould in the broad phase direction. So, the distance between these 2 will be different from the top to bottom; bottom will be less. So, this is called the taper. So, when this taper; that means, this what I am telling

you this x minus delta x. So, this delta x is the taper say from 220, I had mentioned it has become 215. So, 5 millimeter is the taper now the; that you have to express because a mould length again is not fixed for different cast as we have different mould lengths.

So, this has to be for scientific you know comparison you have to express this taper in terms of the percentage; that means, how much of percentage you are giving for the length of the you know mould how much is the percentage. So, that is what is important. So, say you are giving a point nine percent or it can be one percent you know for this type of chemistry is where you have mode of shrinkage. So, the taper is a slightly more and fast sticker type of grades you do not want to give more taper you know because more the taper more be the more will be the sticking.

So, again I as I was telling you depending on whether is a sticking grade or a depression grade your casting parameters have to be identified. So, taper mould tape is one parameter which is again set or decided based on what is the solidification characteristic it is a depression type of bread like AISI 304, you give slightly higher taper say point nine or one percent if it is a sticking type of grade upstrain is say it is 430 which is a sticker type of bread. So, then you give less amount of taper say 0.6 or 0.7 percent. So, what I am now telling is let us keep the taper fixed for 304.9 percent.

So, what we are doing is we are changing the nickel equivalent to chromium equivalent what does it basically means we are changing the chemistry of 304; 304 has a range of chemistry it has not fixed for any grade you see there is a range of chemistry like 304, we will tell u chromium should be between 80 percent to 90 percent nickel should be between say 8 percent to may be 8.6 or 7 percent so; that means, there is a range manganese has to be between something you know other alloying elements carbon has to be between something nitrogen has to be between within range.

So, all alloying elements have a range. So, I have told you what is nickel equivalent nickel equivalent is nickel plus all austenite stabilizing elements like carbon nitrogen copper, these are the elements manganese which are austenite stabilizers; what is chromium equivalent chromium equivalent chromium plus all ferrite stabilizing elements like maybe you have titanium maybe you have some other ferric stabilizing element. So, when all silicon; so, when you combine all these with certain; you know coefficients then you get nickel equivalent chromium equivalent now the ratio of this as I mentioned many

times indicates the chemistry of the stainless steel. So, what we are showing; what is this line? I had mentioned you earlier that 0.55 is the chemistry beyond which; that means, more than when nickel equivalent by chromium equivalent is more than this the peritectic reaction is starting.

So, that is why 0.55 has some lot of significance, it is like 0.1 percent for carbon steel in the iron carbon diagram you find the peritectic reaction starts from 0.1 percent. So, normally that chemistry point one percent is called the so called peritectic grade though the peritectic reaction continuous from 0.1 to 0.5, but around 0.1; I have mentioned; it is called; so called peritectic is because it is prone to depression very much prone to depression because there is delta to austenite solidification is taking place around this chemistry towards in the crucial end of certification area.

So, that is why this is very important we have mode of depression like that like 0.1 percent carbon steel 304 stainless steel is again. So, called peritectic chemistry we called it because the chemistry is near 0.55. Now see what is happening in normal 304 what is being used the nickel equivalent with chromium equivalent is rough approximately in the area of 0.57 or say 0.58 to 0.56; this is the normal chemistry range of 304.

So, what is happening you see as I have told you, since it is near the peritectic zone slightly more than the peritectic, you know chemistry you have lot of incidence of depression formation says maybe around 40 percent depression. So, now, what is the technique what can be done, we are keeping whatever precautions are necessary for continuous casting that we are detain using; that means, mould taper using slightly higher we are using a proper powder as I have told you to get a good heat transfer in the mould in addition to that what we are doing we are slightly changing the chemistry to bring the nickel equivalent to chromium equivalent less than 0.55.

It is possible because all these elements have a certain ranges as I am telling you nickel has a range chromium has a range. So, what we are doing we are decreasing the nickel equivalent by chromium equivalent basically means we are slightly decreasing nickel. We are slightly decreasing manganese maybe we are slightly decreasing carbon and we are slightly increasing chromium slightly increasing silicon in that way everything is done within the range you cannot go beyond the range because it has to be 304 instead of 304 you cannot make 301. So, within 304; what about at the limits you are trying to

control the alloying elements within those limits. So, what is happening? We just see if you can bring down nickel equivalent by chromium equivalent slightly not much from say around 5 7 to say less than 0.54 you look at here 0.54; 0.53, 0.52; what is the incidence of depression is much less is about 10 percent only.

Initially it was 40 percent or more for the normal 304 chemistry. So, what has been done slight adjustment of chemistry has been done to bring it from above the peritectic start chemistry to less than peritectic chemistry 0.55, I am telling you is the peritectic start chemistry. So, from above 0.55 nickel equivalent by chromium equivalent you are bringing it to less than 0.55; you make it say 0.53, 0.54, 0.52. So, it is basically not much of variation in chemistry. So, I can call it minor adjustment of chemistry understanding the solidification sequence here, what is happening delta to gamma transformation send it is in the peritectic region delta to gamma is taking place in the crucial zone of end of solidification in the crucial zone between 90 percent and 100 percent solidification say if takes place, there delta to gamma transformation stress is acting on it.

So, the stress or strain is increasing the tendency for depression. So, the result is high amount of depression if you can control the chemistry to a minor extent within the you know the alloy range of 304 within the chemistry range of 304, we are slightly decreasing the nickel equivalent by chromium equivalent to a value which is less than the peritectic start is 0.55, we are making it 0.54, 0.53, 0.52, we cannot make it very low because it will go beyond the 304 chemistry. So, it has to be minor. So, 304 chemistry basically is encompassed within say the range of 0.58 to 0.52 nickel equivalent by chromium.

If you look at the chemistry range, you will find it is possible to adjust it within this range not beyond. So, within this range, we have modified and seen for the same continuous casting parameters keeping everything same; what is the incidence of depression incidence of depression can come down quite a bit; just by minor control of the chemistry. So, this is called minor adjustment of chemistry within the specification range of 304, what we are getting, we are getting less amount of depression. So, the defect of say depression in 304 which is a depression prone grade normal chemistry will have lot of depression. So, you try to adjust it first with casting parameters as I have told you, we adjust the taper you adjust the powder characteristics you adjust the you know mould rather the oscillation mould oscillation sequence of parameters like you adjust the

frequency you adjust the amplitude. So, after doing all this also for the normal AISI 304 chemistry you will find some amount of depression.

Now, if you if you want to control those depression what can be done is what we have done is basically we have done minor adjustment of chemistry, instead of having nickel equivalent chromium equivalent more than 0.55, this is the dividing line, we have brought it down to less than 0.55, we have brought it down to 0.54, 0.53, 0.52. So, what is happening incidence of depression is coming down? So, this is one very important strategy I had mention to you several times that suitable continuous casting parameters adjusting to the solidification characteristic is very important that is first strategy your casting parameters you have to adjust to suit to rather to take care of the sticking or depression characteristics.

If you have a sticking tendency you know continuous casting parameters will be something, if you have a depression characteristic; that means, what about I am talking is different grades of steel some may have sticking tendency some may have depression tendency for the those grades which have sticking tendency your parameters casting parameter will be something for those grades which have a depression tendency casting parameters will be different, as I have mentioned to you, mould tapered will be different mould powder characteristic will be different mould oscillation parameters will be different secondary cooling parameters will be different intensity of secondary cooling distribution of secondary cooling will be different.

So, speed also possibly you have to adjust it to certain extent. So, all these are casting parameters which have to be decided based on the solidification characteristic, but on top of that I have talking about another strategy; that is minor adjustment of chemistry with minor adjustment of chemistry again you know as I have mentioned 304 like 0.1 percent carbon the so called peritectic grade; here what is happening; if you have nickel equivalent by chromium equivalent which is more than the peritectic chemistry of 0.55, you have some amount of depression quite a large amount of depression rather.

So, you can bring down this depression keeping all other parameters constant by controlling this nickel equivalent by chromium equivalent to less than 0.55. So, it is basically minor adjustment of chemistry, this is one important strategy first I had talked about controlling the casting parameters depending on the type of solidification whether

it is you know sticking or depression types. Now I am talking of another strategy which is minor adjustment of chemistry.

So, by using this chemistry the adjustment we have brought down the incidence of depression in a important grade like 304 is the most popular stainless steel grade, but it is dissect with the problem of depression, you have lot of surface depression and surface depression is bad because under this depression, you may have cracks while you are roiling the material those cracks will come to the surface and the final roll product will have lot of surface cracks and there is a high incidence of rejection because of that.

So, to take care of that improve the quality together with optimum casting parameters; you can use minor adjustment of chemistry this strategy also to bring down the incidence on depression. So, I have talked about mechanical soft reduction, how does it control the central segregation and central crack I have talked about minor adjustment of chemistry for 304 type of grade, how it can control the incidence or depression.