Welding Metallurgy
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Lecture No. 50
Lamellar Cracks and Stress Corrosion Cracking

Welcome to the lecture on lamellar cracks and stress corrosion cracking. So, we are going to talk about these two different types of cracks which take place. Lamellar cracks are also known as lamellar tearing and stress corrosion cracking is a type of cracking where you have the chance of cracking because of the subjection to corrosive environment or other factors. So, we will talk about these two cracks.

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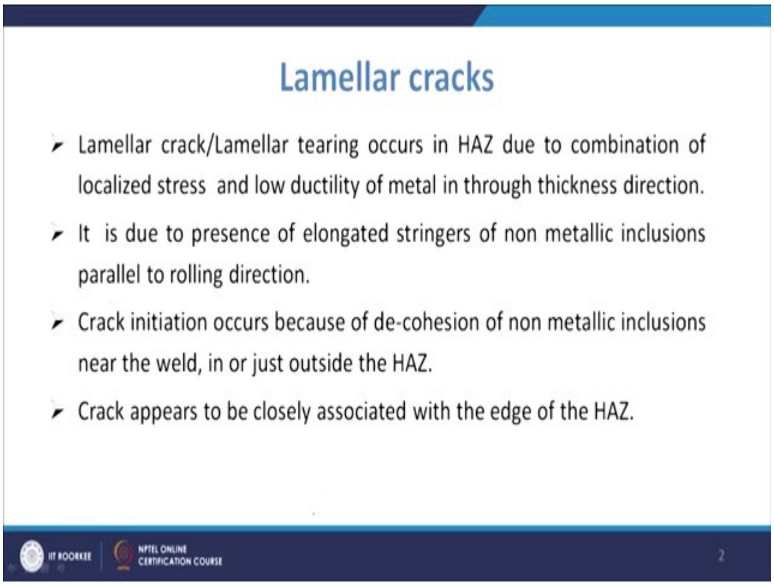

So, lamellar crack or lamellar tearing that is occurring in the HAZ due to combination of localized stress and low ductility of metal through thickness direction. So, basically, in that through thickness direction these tearings are observed and it is because of the combination of the localized stress as well as the low ductility of the metal.

So, what is happening is that, this is due to the presence of the elongated stringers of non-metallic inclusions parallel to the rolling direction. So, when the metal is subjected to rolling you will have the elongated stringers, so they are basically the stringers of the non-metallic inclusions. Normally you have the MnS that is manganese sulfide or you may have the oxide silicate type of inclusions that are there.

So, it is because of the presence of these materials that you will have the decohesion, that is what we will see. The crack initiation basically occurs because of the decohesion of these non-metallic inclusions near the weld, in or just outside the HAZ. So, basically, when you have these non-metallic inclusions there will be decohesion that will be occurring with the weld metal of these inclusions and that basically will lead to the formation of these lamellar tears.

In the case of lamellar tearing, these cracks are appearing closely associated with the edge of the HAZ. So, you will be looking at it normally, you will be seeing it close to the edge of the HAZ.

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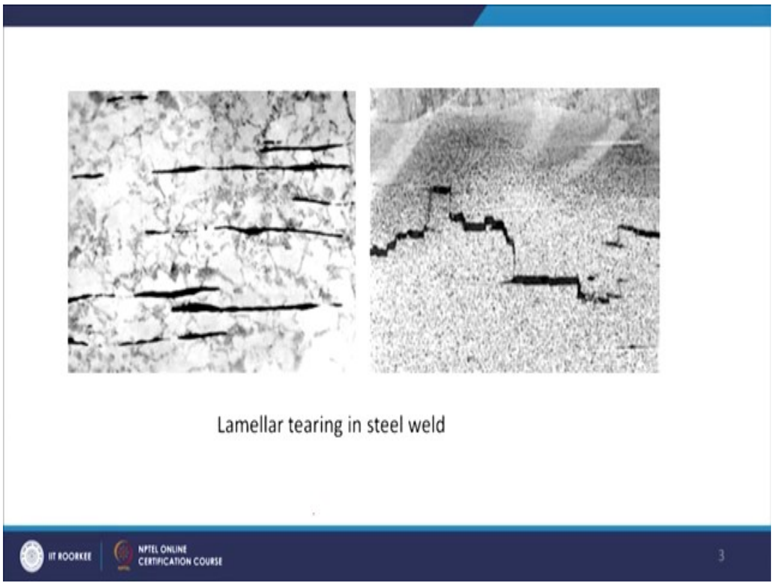

Now, if you talk about the lamellar tears and if you try to visualize, so this is how the lamellar tear is looking like.

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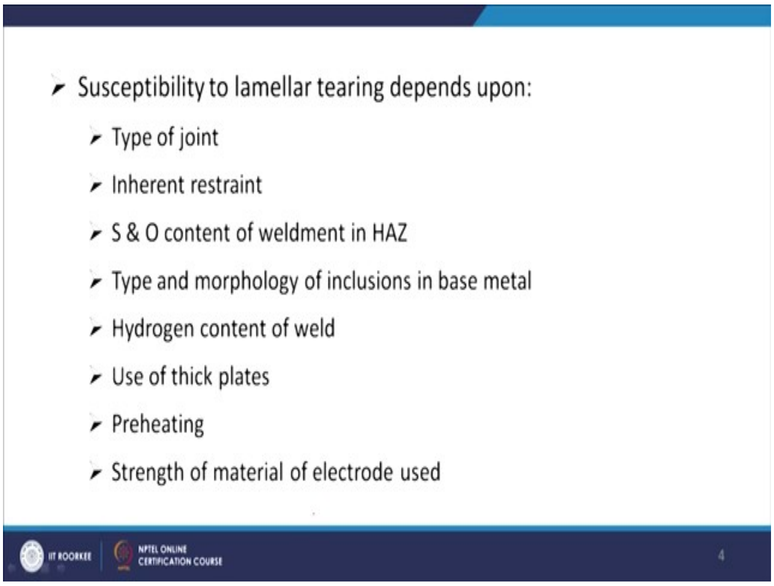

So, if you talk about the susceptibility of the lamellar tearing, the material whether it will be susceptible to the lamellar tearing that will be depending upon the, one is the type of joint, second is the inherent restrain that is there. Then, you have the sulphur and oxygen content of weldment in the head affected zone. Then, type and morphology of inclusions in the base metal. You have the hydrogen content of the weld and the use of thick plates.

So, apart from that you have also the preheating. So, preheating is another factor and also the strength of the material of the electrode which is used, that also is among the factors which are making it either more or less susceptible to the lamellar tearing. So, if you look at the effect of hydrogen basically, so it will be related to the presence of or the occurrence of embrittlement rather than the cold cracking.

So, you have the probability of having the hydrogen embrittlement in those cases. Now, if you talk about the preheating, so preheating will be reducing the chances of lamellar tearing as the point indicates. So, especially when your stoop potentials are present, in those cases, the chances of or susceptibility to lamellar tearing is basically reduced in the case of preheating.

Also, if you are taking about the strength of the material of the electrode, if you take the electrode material of small strength and within the design requirements of course, then, in those cases the weld metal will have the ability to accommodate the strains which take place because there will be contraction strains that will be caused while cooling. And in those cases, you will have less chance of or less susceptibility towards the formation of these lamellar tears, and so you will have more resistance to the lamellar tearing.

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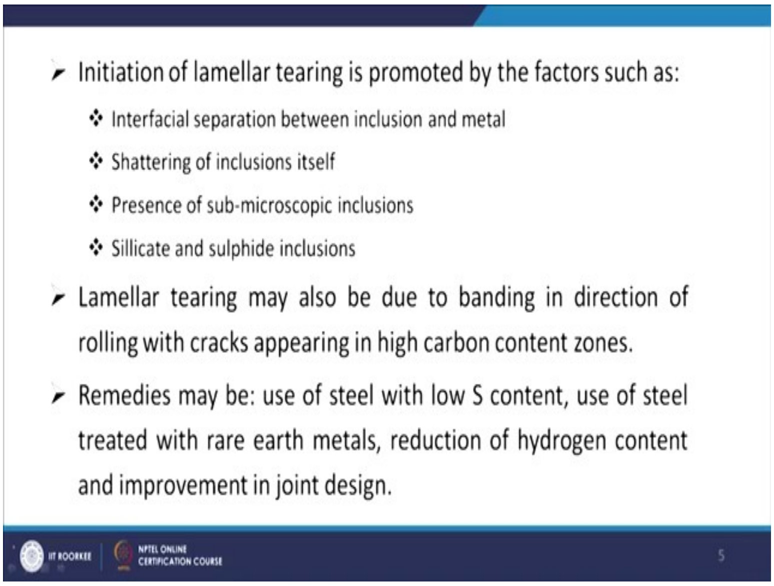

Now, if you talk about the factors which are basically responsible for the initiation of the lamellar tearing, the lamellar tearing initiation basically is promoted by many factors. And among them you will have, one is the interfacial separation between inclusion and the metal. So, basically the separation will be there in between the inclusion which we have seen, that you have the sulfide or the silicate inclusion or oxide inclusions are there.

So, that separation which will be taking place between these inclusions and the metal, that is one of the reasons. Another is the shattering of inclusions itself, many a times the inclusions shatter, and then at more locations you have the inclusions particles and also if they shatter, then the cohesion which is there between the metal and the inclusion, although it is less, but then by shattering process that further reduces.

So, that also increases the probability of having the initiation of the lamellar tearing, then, the presence of sub-microscopic conclusions. So, if you have the sub-microscopic conclusions and in the presence of improvements itself that may increase the probability of the initiation of the lamellar tearing. Then, as we have discussed that you have the silicate and sulfide inclusions are there typically.

So, if these inclusions are there, then they will be increasing the chances of initiation of the lamellar tearing of the material. So, that is what normally we see in the case of the lamellar tearing. Now, if you look at the other reasons, the lamellar tearing may also be due to the banding in the direction of rolling. So, bending is, as we know, this is the segregation of carbon in bands.

So, in many zones you see this carbon and in those cases you have the appearance of the cracks. So, that can be seen in the case of lamellar tearing. We have seen the pictures. That is what you see, these bands. These are the bands which are seen that is segregation of these carbon which is seen in bands. So, this is the example of typically, you know, the formation of the lamellar tearing. So, what you do, you normally do certain measures.

You take certain measures, you have to have certain remedies for occurrence of these lamellar tearing. Now, for that, what you do is you are using the steel with low sulphur content. As you know that if the sulphur will be less, then you will have less chances of having sulfide inclusions. So, you try to have lower value of sulphur, lesser than point 0.007% even in that case. So, in those cases, you can get rid of these lamellar tears.

Then, you have other way by which you can get rid of these types of tears, it is that you treat these steels with rare earth metals like cerium or so. So, in those cases, the chance of having these lamellar tears is reduced. Then, you have also to use those processes or you have to adopt those methods by which you can ensure that there will be less amount of hydrogen that is hydrogen content of the weld will be reduced.

So, therefore, that also you will have to have. There are many ways in that case for reducing this hydrogen content of the weld. It may be related to either the selection of proper electrode by the heating the electrode or taking care of the aspects related to the coating of the electrode or so. So, that way you have to reduce, you have to have control on the hydrogen content of the weld.

Because hydrogen is very much responsible for this lamellar tearing because that hydrogen is leading to the embrittlement, and in those cases your lamellar tearing may occur. Then you can also have the improvement in the design of the joint. So, by improving the design of the joint you can ensure that there will be less chance of having these types of defects like lamellar tearing.

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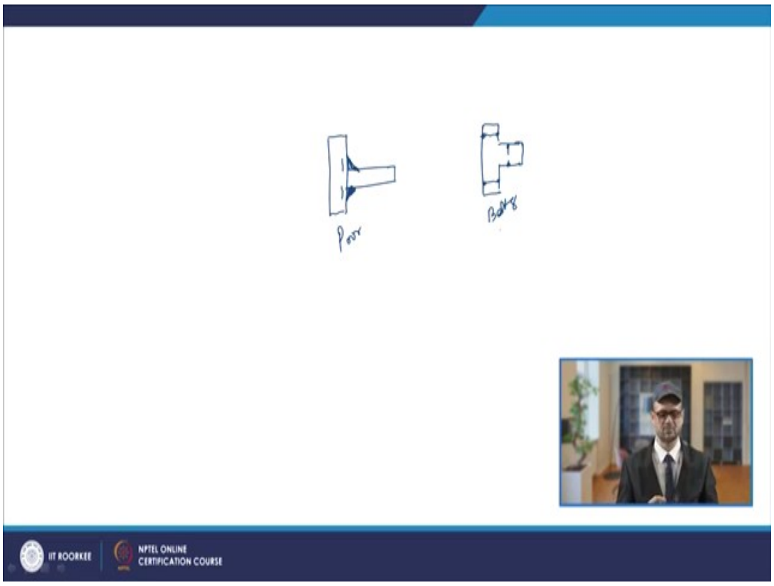

For example, if you try to have the designs, so what you see is that you may have designs like here and if you have a fillet weld, if suppose it is going like this, so in these places you may have the chance of the lamellar tearing. And if you go for proper, somewhat better design, so you can go for some fixing, so that way if you do like this, so in those cases, your designs are improved.

So, this way the chances of lamellar tearing will be, so this is a poor design, and this is a better design. So, you can change the joint design and that will lead to decreased chances of having the lamellar tearing. So, next, that is what we have discussed. These points we have already discussed, what are the reasons for which these are promoted. The next type of cracking which is very much important again is the stress corrosion cracking.

Now, what is happening is that many a times when you have the welding going on, you have the alloying ingredients which are coming from the electrode coverings and also fluxes. These alloying elements which are coming from these electrode coverings or fluxes they are very common. So, commonly they come into the weld pool.

Now, what happens is that they dissolve in the weld pool, but due to fast cooling what is happening, because the cooling in welding is fast because of many reasons, that is what we have studied so far because of the presence of weld metal on both the sides having higher thermal conductivity. So, you are getting lesser time to properly diffuse or mix or proper distribution.

So, what is happening is that you will have the localized region where you have the high alloying elements, more highly alloyed regions will be there, a few regions which will have these alloying ingredients in a larger quantity, then that is found in the bulk weld. Now, what is happening is that often when you have the formation of these regions, often these regions are the martensitic structures, and that will be giving you the problem in service.

So, in future that leads to the problem in the service and that is also because of these stress corrosion cracking. What happens is that you have the formation of these hot spots which are formed and and these hotspots which are formed they are normally encountered in case of SAW. So, in those SAW processes when there is use of manganese, mostly in those cases what happens is that some of the molten slags they enter into the weld pool.

And then it starts solidifying. This is also found many a times in the case of shielded metal arc welding also and also the cored wires. These hotspots which are found they quickly solidify and there is not complete dissolution. Since there is no complete dissolution as well as there is no proper homogenization, both these things are basically lacked, and that basically results into stress corrosion cracking.

So, if you talk about the mechanism of the stress corrosion cracking for the carbon steel welds, if you see when these carbon steel welds are exposed to the severely corrosive conditions like warm or sea water, so they will be attack, that will be concentrated upon the HAZ or the weld metal. So, basically, that limits the life of that weld. So, the effect of this stress corrosion cracking is that once that attacks, then that will be limiting the life of the HAZ.

Again that depends upon what kind of stress relieving treatment has been given. So, the stress corrosion cracking of HAZ basically will occur if the welded joint which has not been given the stress relieving treatment and they are basically exposed to these aqueous solutions of hot concentrated caustic soda and, in that case, weldment is subjected to very very high level of stress.

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- When carbon steel welded joints are exposed to severlely corrosive conditions, there is a tendency of attck on weld metal/HAZ and life of weld may be reduced.
- Stress corrosion cracking of HAZ of weld occurs if welded joints that have not been stress relieved are exposed to aqueous solutions of hot concentrated caustic soda and the weldment is subjected to high tension level.
- These cracks in carbon steel are typically intergranular while they are trans-granular in austenitic stainless steel.

So, when these carbon steel welded joints are exposed to severely corrosive conditions, then there will be a tendency of attack on the weld metal or HAZ and life of weld metal may be reduced. So, that is what we have studied, the stress corrosion cracking of HAZ of weld occurs if the welded joint have not been stressed relieved and are exposed to the aqueous solution of hot concentrated caustic soda.

So, that way, the weldment is stressed in tension to a very high level. So, one is that in that atmosphere it is exposed and then also it is under tensile environment to a very high level. If you talk about the carbon steels, they are typically these type of cracks which you observe. They are normally inter-granular, and if you look into the alternating austenitic steels, they are normally found as the trans-granular type of cracks.

For these carbon steels, more importantly, if you talk about the stress cracking reagents, they are the caustic soda that is NaOH and ammonium nitrate. So, these two are the stress cracking agents. And apart from that, it has also been seen that these coal gas liquors or you have cyanides and sulphates, they also act as the stress cracking tendency raisers. So, they increase this tendency to go for stress corrosion cracking.

So, basically, for that, there will be a graph. As we see, for carbon steel you have caustic soda and ammonium nitrate, they are the important stress cracking agent and there is a limit of concentration and temperature value above which the stress relief of joint is required. So, basically what is happening is that, if you talk about the environment in which the material is to be subjected to, and so for that depending upon that concentration of the caustic soda and the temperature at which it is to be worked, based on that you can ascertain whether you require to give these treatment or not.

So, if it is falling in that case in a danger zone, then you have to give the stress relief treatment. So, basically that can be represented by a graph normally. You will have the temperature on the ordinate and this is the caustic soda concentration.

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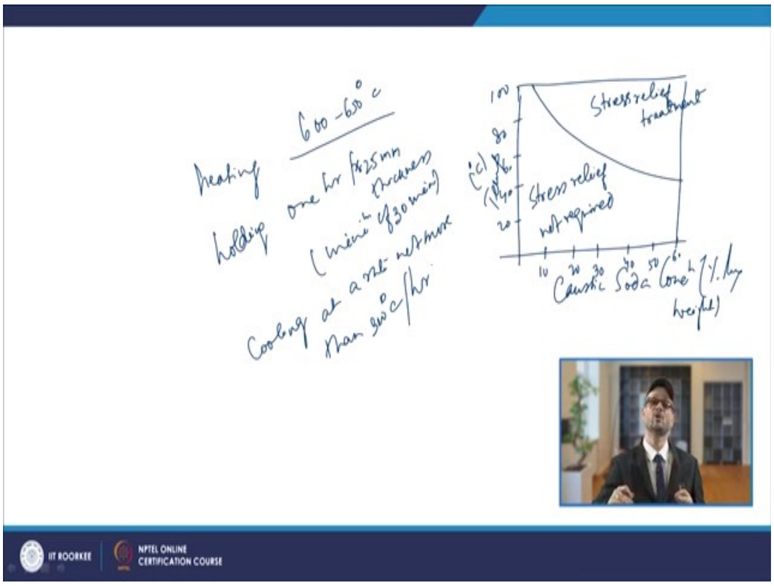

So, the caustic soda concentration will be percentage by weight, and so it will be 10, 20, 30, 40 like that it will move. Now, if your caustic soda percentage is less, it can even go to a higher level. And normally the graph goes like this and this will be your 100, so you have 80, then you have 60, 40, 20, and so. As you see that if your caustic soda concentration is increasing, then after this temperature you need to give the stress relief treatment to the material.

In this case, if it is falling in the below zone, here the stress relief is not required, and here if the material is going to be utilized or going to be used in that corrosive environment, suppose the temperature is 80 °C, this is temperature in degree C, so if 80 °C is there, this caustic soda concentration should not reach may be close to more than 16 or 17, so that way according to this graph.

If that is more, than you have to give this stress relief treatment. So, you have to give a kind of treatment in which what you do is you are going for heating, you are the heating and holding that in between the temperature of 600 to 650 °C. So, you are heating to this temperature, then you are holding for a specified time, so, holding for one hour per 25 mm of thickness.

So, minimum of 30 minutes you have to keep for whatever thickness it be, let it be even less, so minimum of 30 minutes you have to keep, and then you have to do the cooling, so cooling at a rate not more than 300 °C/h. So, this kind of treatment you have to provide, then the material will not be subjected to stress corrosion cracking even if it is used in corrosive environment.

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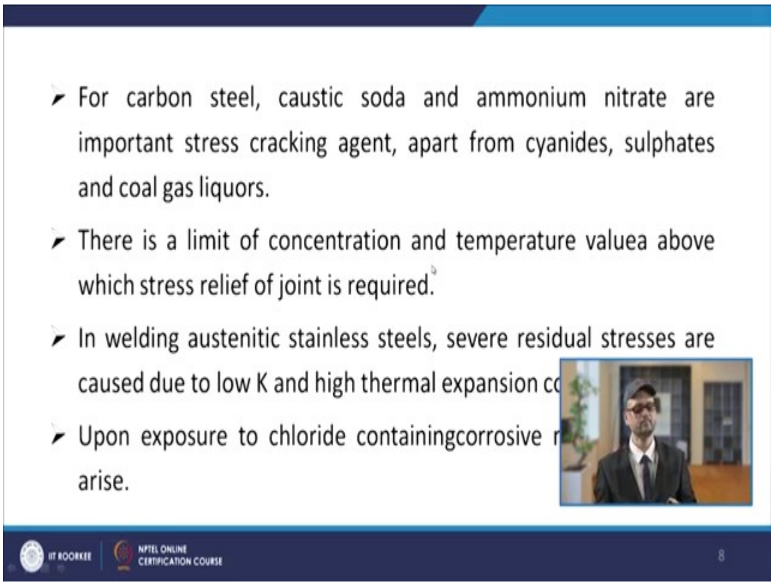

So, in that top, the area that stress corrosion cracking will be looking like, and in this under the corrosive environment how the cracking takes place that can be seen from this figure. So, these are the example of stress corrosion cracking which is basically observed.

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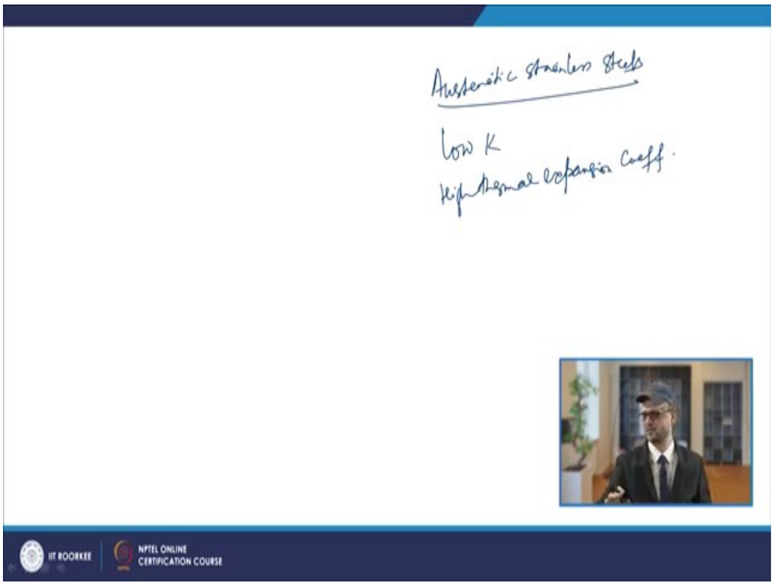

Now, in the case of the austenitic stainless steels, if you look at the stress corrosion cracking of the austenitic stainless steel, so in austenitic stainless steels for these materials you have low thermal conductivity and you have high thermal expansion coefficient. So, you have low K and high thermal expansion coefficient. So, what is happening is that when they are limiting they are subjected to the chloride containing corrosive media.

In that case, these stress corrosion cracking may occur. So, that is what we have also seen, that when we are doing this welding of austenitic stainless steels you have severe residual stresses or basically, you know, cost, and that is because of the property of these type of stainless steels, that is austenitic stainless steel. They have low thermal conductivity and high thermal expansion coefficient, so they will have more contraction or expansion.

So, in those cases when you are subjecting them to this chloride containing corrosive environment, in those cases you will have the appearance of the stress corrosion cracking, and if you look at these crackings, they are normally trans granular type of cracking and also the branching is also seen.

So, what you do is that, when you provide, in those cases, when you provide this heat treatment, so, this stress relief heat treatment is carried out, so there will be precipitation of the chromium carbide that will be taking place because in the case of this austenitic stainless steel because of the chromium you will have the precipitation of the chromium carbide. But that is to be carefully seen.

And although this stress relief can be also obtained using this solutionizing also so that you can dissolve this chromium carbide which is at the temperature level of about 1000 °C. In that case, there may be new residual stresses also that can be developed during that subsequent quenching. What we have seen is that you will have to have proper treatment that is to be meted out to these materials.

If you feel that this material is going to have the stress corrosion susceptibility, in that case, you have to give the proper type of heat treatment that is stress relief treatment so that you have lesser chances of having these stress corrosion cracks in the materials. And also if you use these low carbon or stabilised grains of materials, then they can avoid the formation of these stress corrosion cracking because they will allow the material to cool slowly after the solutionizing.

So, in those cases, you can ensure that the undesirable effect in terms of these stress corrosion cracking can be avoided by having such grade of materials. So, in a nutshell, we talked about these different types of cracks which we have studied like in this lecture, we talked about the lamellar tearing and the stress corrosion cracking. Apart from that, earlier we had studied about the reheat cracking or chevron cracking.

So, these are basically categorised as the special type of cracks which occur in different materials and typically we have talked about the material that is steel, and then you can have also the analysis based on the other kind of materials like nickel based materials or the materials which are used for specific applications like in nuclear. So, these cracks and all that you have to have more focus oriented studies on the those critical components used in these nuclear industries or nuclear vessels or so.

Accordingly, when you are going to use them, or the component which is used in the marine environment, so there you have to go for the special kind of treatment so that they do not undergo this kind of crackings. Thank you very much.