Welding Metallurgy
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Lecture No 46
Introduction to Cracks in Welds

Welcome to the lecture on introduction to cracks in welds. So, as we have studied about the welding and we have seen the consequences of, stresses which are built up in the, during the building process. So, that leads to development of residual stresses then that leads to distortion. And there are many other kinds of discontinuities, which arise and among them, the cracks are among the worst. So, I mean it can be gauged in the sense that even weldability is in terms of, its ability to resist the cracking or how much it is prone to cracking.

So, either during or after welding, the crack develops, so even weldability is also defined on that basis. So, cracks basically are, very important to be studied and we must know that what are the different types of cracks, then under what conditions they occur. So, in this lecture we will have some introduction about the cracks and then, during this week we will have more discussion on the types of cracks and specific type of cracks, and their consequences are so.

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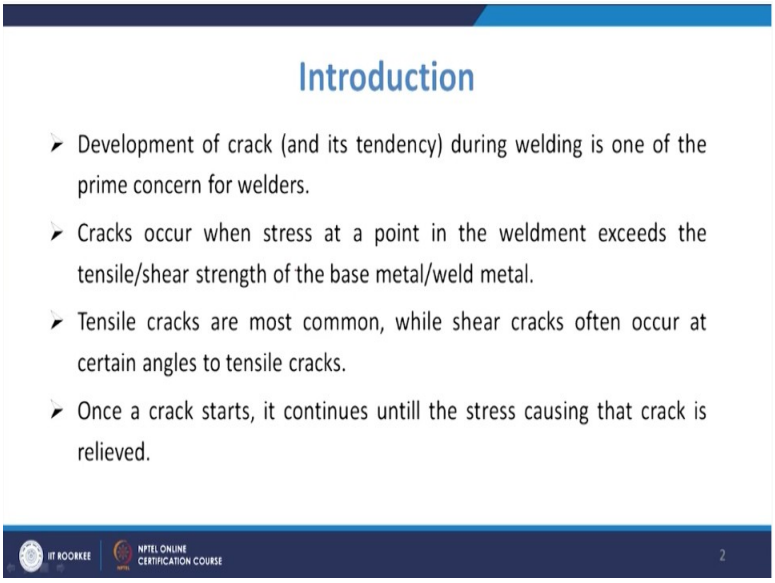

So, as we should be knowing that the development of crack and its tendency welding is one of the prime concern for welders, because they are very much concerned about the crack. Now, how cracks occur. So, as we know that, during that process, you have certainly thermal fluctuations going on the specimen weldment is subjected to thermal treatment, thermal

socks. So, crack will occur when stress at a point in weldment exceeds the tensile or shear strength of the base metal or weld metals.

So, that is what is happening because you will have the development of stresses and if the stress value will reach a value which is more than the ultimate tensile strength or ultimate shear strength of the base metal or weld metal, so, then the cracks will occur. It will occur at any place, it may occur in the weld metal zone, it may occur in the base metal zone, it may occur in the heat affected zone and wherever cracks occur, so, that is the basic reason.

Because, at some point, when the stress value will be reaching beyond certain limit and mostly that limit is the ultimate strength value. So, in that case, the cracks used to occur. So, normally cracks do not occur when the material is under compression. So, that is normally, the cracks are, occurring in tensile mode and that is why tensile cracks are the most common because when we apply the compression load, then there is a very less chance that the cracks will be getting opened.

Basically, normally you have these small cracks and then during the process of operation or during the subsequent processes, if these cracks are opened, then only that that leads to the failure of the material. Because, once it opens, then on a particular cross-section the area will reduce. So, you will have the load bearing capability at that section will start reducing because the area gets reduced. So, normally in comparison, you will not hear, at most of the time you will not hear that the compression causes the cracks, but in fact tensile and shear.

We will have tensile cracks or the shear cracks. So, tensile cracks are basically, most common. I mean, in the sense and also the shear cracks, I also while wish to mention that is why you see that, we do the peening action, we have seen that we do some peening action. So, that is what we go for these peening, because that will put the metal under compression. So, that is how these development of crack will be somewhat demotivated or it will not be allowed to grow.

So, that is why, peening is done, but however peening is not always allowed by the welding codes. So, because that may not be the appropriate way of peening by the welder or so. So, as we studied that tensile cracks are the most common and they will be occurring either in the weld metal or in the base metal. So, the tensile cracks on one side and another side is the

shear cracks because that will be occurring because of the shear stresses. And they also occur and mostly they will occur at certain angle to the tensile cracks.

So, they will be appearing in the line running of at an angle from the direction of the stress. So, once a crack starts, then it will continue through the weld and it will continue till the stress causes the cracking, I mean that is causing the cracking that is a relieved. So, basically, in case of cracks, one is the onset of crack or the appearance of the crack and then its propagation.

So, that propagation continues and that will continue till the stress, which is causing the crack that is relieved. So, many a times we try to relieve that stress, so, that way also the tendency of crack proposition will normally try to decrease. So, that is why, it is written that it will be propagating till that cause which is there for creating the stress that is relieved. So, there are many cases when you will see that in the case of ships or so, you will see that the ships have broken down into two pieces.

So, basically there are cracks and that cracks basically will go on widening. And if the proper due attention has not been paid, then in that case, that will be broken and it will be catastrophic failure it will be split in the 2 parts. So, because of the small crack, initially which looks very insignificant, very small crack, but then that will start growing and then at one point of time, it will be breaking into 2 parts.

Similarly, cases can be observed in the case of pipelines, which carry the high pressure fluid and in that also the crack propagates very fast and so, there also you will see that the crack will propagate and the pipeline will burst. So, that is how, so even the small cracks in those specific applications cannot be ignored. So, basically their attention on these cracks is very important.

Now, what happens that when you are going for multilayer welds, now, in those cases, most frequently the cracks will occur in the first layer of the weld metal in the root joint, root zone of the weld joint. So, you have to have the proper attention on the first pass in that large joint. So, what we do is normally we try to find the presence of cracks using the nondestructive testing methods and then, once ensured, we just move ahead.

So, many a times what we do is that, we normally go for preheat the parent metal before the welding. So, what will happen that will be decreasing the tendency to form martensite because what happens that when there will be transformation of martensite from the other phase austenite or so. So, in those cases stress buildup will be maximum. So, in those cases the chances of formation of, martensite is more, I mean, crack also is more. So, once you do the preheating so that cooling rate will be decreasing.

And in that case, your chances of formation of the martensite will be lesser and that way, your chance of having the crack also will be less. So, these are the ways by which we can somewhat reduce the formation of cracks. Now, we will talk about, the classification of cracks, we must know that, how many types of cracks are there and we will discuss few of those cracks in this lecture.

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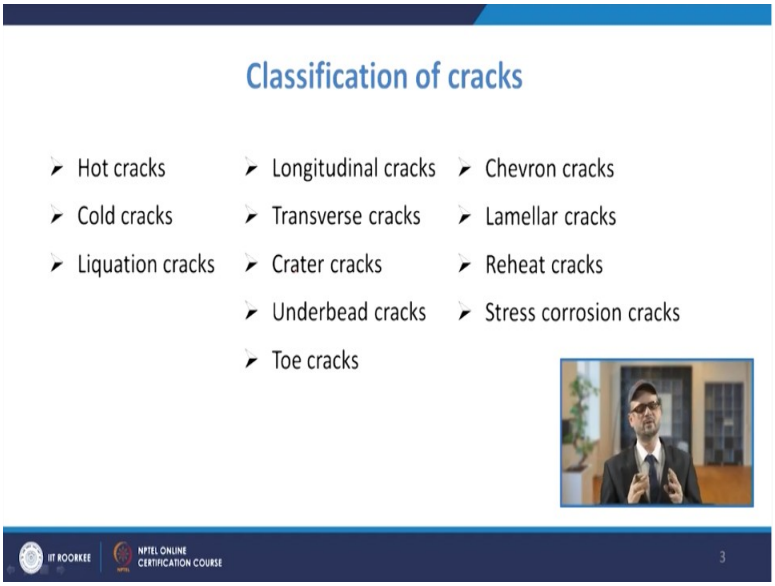

So, coming to the classification of cracks, we must know, that cracks can occur in the weld metal or in the HAZ**,** it can occur anywhere. Now, sometimes they will be originating in one zone and they will be spreading and going to the other zone. So, we are basically categorizing the crack. Normally we categorize in 2 types, hot cracks as well as cold cracks. Now, if you talk about the hot crack.

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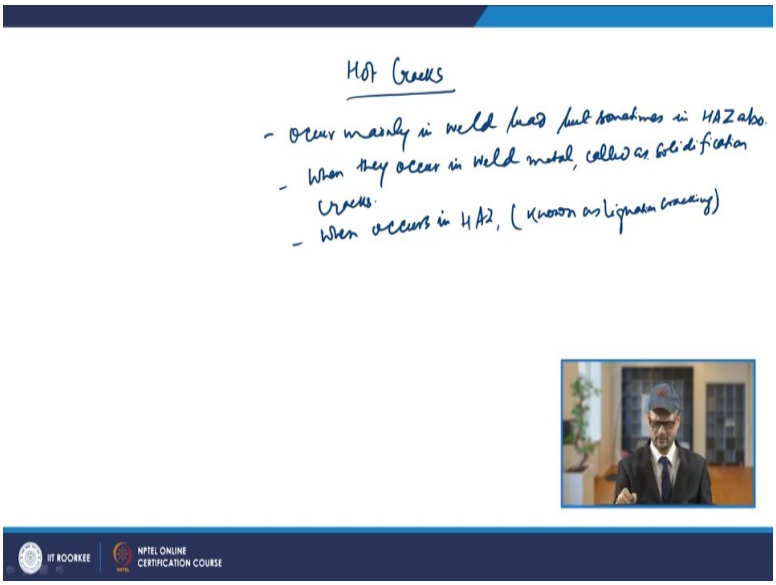

So, coming to the hot cracks, so, as the name indicates, it will be during that hot temperature range, so, they will be occurring normally in the weld bead and sometimes, they may develop in the HAZ also. So, many a times, mostly it will be, we are going to talk about that normally in the weld bead and many a times we also call it as the solidification cracks. So, when they occur in that weld metal, we call it as solidification cracks and when it occurs in the HAZ, in that case we call it as the liquation cracks.

We will study about these cracks more because in the case of HAZ, so there, there will be different kind of mechanism. So, you will have the, some phenomena which is occurring on the grain boundaries, you have the presence of low temperature, eutectics, because of that these cracks are likely to occur. So, they are known as liquation cracks, so when occurs in HAZ, so it is known as liquation cracking. So, solidification cracks that is there in the case of weld bead.

So, they occur basically when the metal is very, very hot. So, in those cases as we see, when we talk about that, in the area of weld beat, so, the temperature is very high, it will be just below the solidus temperature. So that will be normally the case in the case of hot cracks or solidification cracks. And there will be normally, if you talk about the solidification cracks, there will be normally interdendritic, there will be random grain boundaries, so they will be following the random part of grain boundaries along the segregated conditions of impurities.

So, segregated concentration of impurity, so, that will be there in those, in that solidification cracking and this is because of the solidifying weld metal. So, that happens in the case of

these solidification cracking and this is happening because of the oxide formation which is there. So, once you have the start of the hot crack formation, then these oxide films are formed. Now, these hot cracks which are formed, they may be intercrystalline also following these lattice layers within the grains.

So, that may be also the nature of these hot cracks. Then, if you talk about these hot cracks, the factor which will be promoting these hot cracks, so there are different factors which promote this formation of the hot cracks. And these factors are, like you have the solidification structure, then you may have the segregation, you have the stress value in the weld metal, you have thickness of the material, restraint and all that, so that we will discuss when we will talk more about the type of these cracks.

Then, comes the cold cracks. So, before that, you have the liquation cracking. So, as we discussed that, after the solidification crack, you have the liquation cracking.

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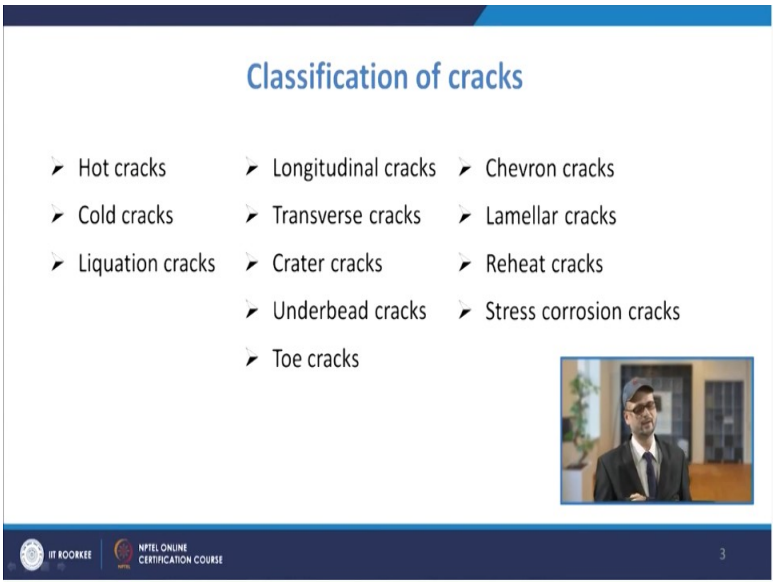

So, this is your hot cracks, then as we have discussed about the liquation crack, so this liquation crack, when you have the crack in the HAZ zone then it is known as the liquation crack and it will be occurring you have the high heat input like in the case of electroslag or the submerged arc welding. So, in those cases, you have also the condition is there when you have the high ratio of Sulphur and phosphorus with a low manganese content, in those cases, these kind of cracks are basically promoted.

So, that is, happening in the area of HAZ. So, that is more related to the crack in the HAZ

area. Then, another type of crack which will be basically, so, normally you have hot cracks and cold cracks, so anyway liquation crack will be a part of the hot crack only and then you have the cold crack. Now cold crack basically is also known as the hydrogen induced crack so, or it is also known as the delayed cracking. So, it is also a very serious type of crack and it is normally occurring because of the presence of hydrogen in the weld.

So, that way when you categorize you also call it as the hydrogen induce cracking HIC many a times. So, the reason for these cracks will be that you have the presence of hydrogen in the weld metal, you have the presence of high stresses and you have the susceptible macro structure that is martensite formation and normally since it is occurring at the lower temperature range, so, maybe from 200 to maybe -100 °C also. So, so that is why it is known as the cold crack.

Now, depending upon the nomenclature, location and orientation of the weld cracks, there is another classification, that way you classify these cracks in other types also that is shown here. So, you have the longitudinal cracks, you have transverse cracks, you have crater cracks, you have underbead cracks, you have toe cracks. So, normally now when we talk about these weld metal cracks, so, you will have these are like if it is in the longitudinal direction, so, you will have the longitudinal cracks.

Similarly you have the cracks which is in the transverse direction, so, you will have the transverse cracks. So, you will have basically in the weld metal zone, you will have the cracks if it is occurring in the longitudinal direction, it is known as the weld metal longitudinal cracks. So, you will have, they will be appearing if you talk about weld metal cracks.

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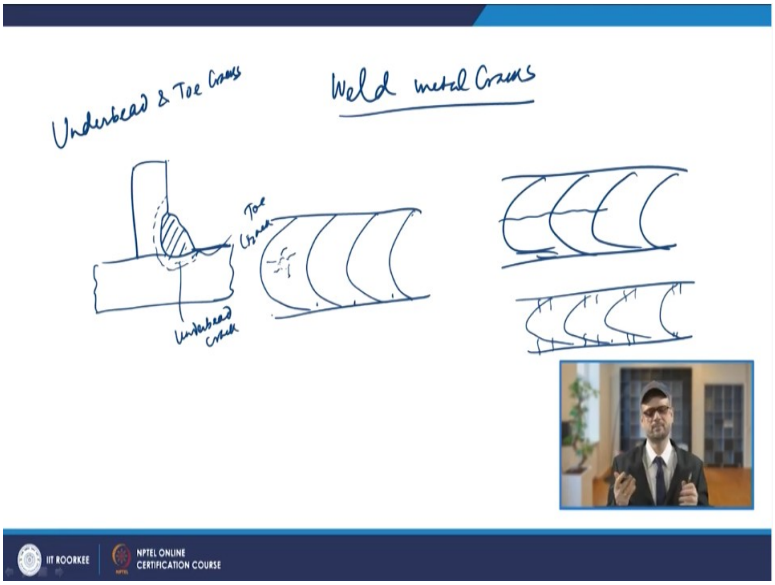

So, if your weld bead is going like this, so, if the crack is appearing in this longitudinal direction, so, and if it is your weld metal, so this is known as the longitudinal weld metal cracks. Similarly, you may have the presence of the cracks in the transverse direction. So, if your weld bead goes like this and if your cracks are coming like this in this direction then it is known as the transverse weld metal cracks.

So, this way you may have, depending upon the way they are oriented, you will have the name such as the longitudinal cracks or transverse cracks. You have also crater crack, so, basically they appear in the crater region, so, you have a star shaped on the crater, the weld metal zone will be like this and you have the crater here so, on those craters you will have in the star shape, so, that is normally star shaped cracks inside, so they are known as the crater cracks, they are the longitudinal cracks, they are the transverse cracks.

You may have the cracks in the base metal also. So, you will have the longitudinal base metal cracks, you may have the transverse base metal crack. So, outside the weld metal, if you have the crack which is there in the direction of, in the longitudinal direction, of welding. So, that way, that is known as the longitudinal base metal cracks, then you have the transverse base metal cracks. So, this way you will have the different types of cracks. Then, there are other types of cracks depending upon the position where they occur.

So, in that you will have the underbead and toe cracks. So, **so** where they are occurring, below the bead or on the toe. So, on that basis you will have the classification of these cracks as underbead and toe cracks. So, if you if you take a fillet weld suppose, if you are making a

fillet weld, if you are making a fillet weld, suppose you have one fillet joint, so that is occurring here and this way you will have.

And this is your fillet, so in that case as you see, so, you will have this plate on this side and this plate on this side. Now, in this case, you may have the crack. So, suppose, now in this case, the crack if it is appearing suppose here, so, that is normally known as the underbead crack. And if it is happening here, then it is known as the toe crack. So, depending upon the places where they occur, you will have these underbead as well as the toe cracks. Then, there are also specific type of cracks.

So, that occurs also in specific cases, they occur in specific environment or under specific conditions, these cracks also appear and in that category, you have cracks and such as the chevron cracks, lamellar cracks, reheat cracks, stress corrosion cracks. So, these cracks they are the special kind of cracks, which are occurring and we will be discussing about these cracks when we talk about these cracks in particular.

But, otherwise, just for the introduction of these cracks, we must know that these are the cracks like these chevron cracks which is there. So, basically they are the intergranular and transgranular type of cracks, which are observed and normally they are associated with the SAW fixtures.

So**,** and sometimes also with the basic coated electrodes, so, they are found and these cracks normally what they are found is, they are found to be also told as the 45° cracks or staircase cracks, because, they will be occurring at 45° to the weld axis.

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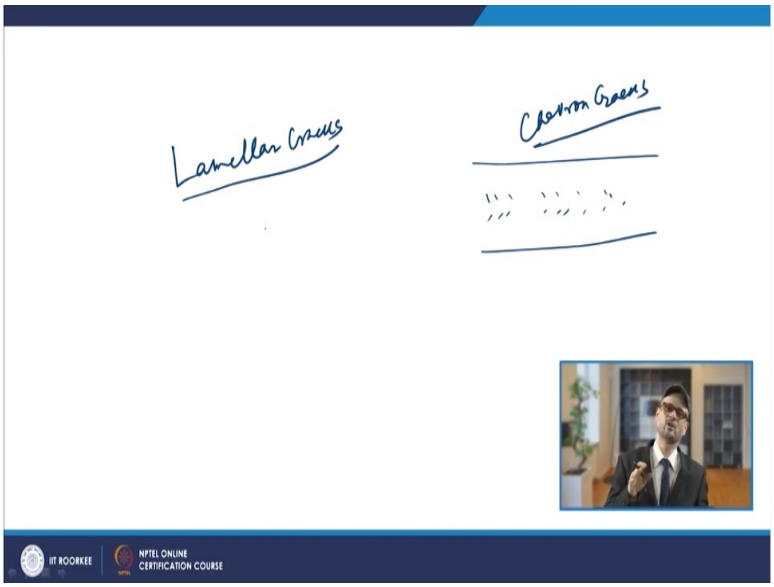

If you look at the cracks, so, if you have the welded plates, so weld axis so this way you will have on this side they will be having your this kind of cracks in the middle. So, this way, you will have these cracks normally in the thick section carbon manganese plates, where you have a high heat input processes like SAW or so, these type of cracks are caused, because of the loss in the ductility in the steel. So, that we will discuss, so that is known as the chevron type of crack.

So this is your Chevron cracks. Then comes the lamellar cracks and they occur in the HAZ, so these lamellar cracks, these occur in the HAZ zone due to localized stress and as well as the low ductility value. So, in this through thickness direction they will be occurring. So, and this is because of the elongated stringers of nonmetal inclusions, that is parallel to the rolling direction. So, in those cases, you will have these lamellar cracks, lamellar tearing will be observed in those cases when it subjected to the rolling.

So, in those cases, parallel to the rolling direction, these kind of cracks are normally observed and it will be again depending upon many factors like the joint, restraint, and then sometimes the presence of some alloying elements like sulfur and oxygen contents. So, that way these type of cracks, that is your lamellar cracks. Then in that specific type of cracks, we have other category also. So, then you have the reheat cracks.

Now, these reheat cracks also are found, they are basically also known as the post-weld heat treatment cracking. So, we have already seen that many a times we do the post-weld heat treatment of the specimen and to relieve those residual stresses. So, basically it is very rare

type of cracks which occur. So, they are also known as the post-weld heat treatment cracking, PWST cracking and they normally are restricted to some special kind of steels.

And there also you have, it is seen that normally you have the elements like chromium, molybdenum, vanadium, or boron. And mainly found in the heavy sections these kind of reheat cracking is observed in the case of this heavy sections it is found and normally it is possibility maybe they are in the case of coarse grained weld metal and apparent steel.

So, there chances of these reheat cracking is there in the case of weld and in the last category, you have basically the presence of we have to know something about the stress corrosion cracking, so, that we are basically we must be acquainted with this term because, although this is also one of the very serious type of cracking.

So, in this case what is happening that many a times, when you have the, because in welding, you have the high cooling and many a times there will be some, because of the improper diffusion, some of the elements which are dissolved and in the later part basically that lead to the cracking that is the corrosion cracking because of the stress levels, so, that is your stress corrosion cracking. So, you will have idea about these cracks in our coming lectures. Thank you very much.