Welding Metallurgy
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Lecture No 48
Specific Weld Cracks

Welcome to the lecture on specific weld cracks. So, in the last lecture, we talked about hot and cold cracks and we also discussed among them the liquation cracking also. Now, we will talk about some specific weld cracks and these names are given because of the positions or their orientation and shape and so.

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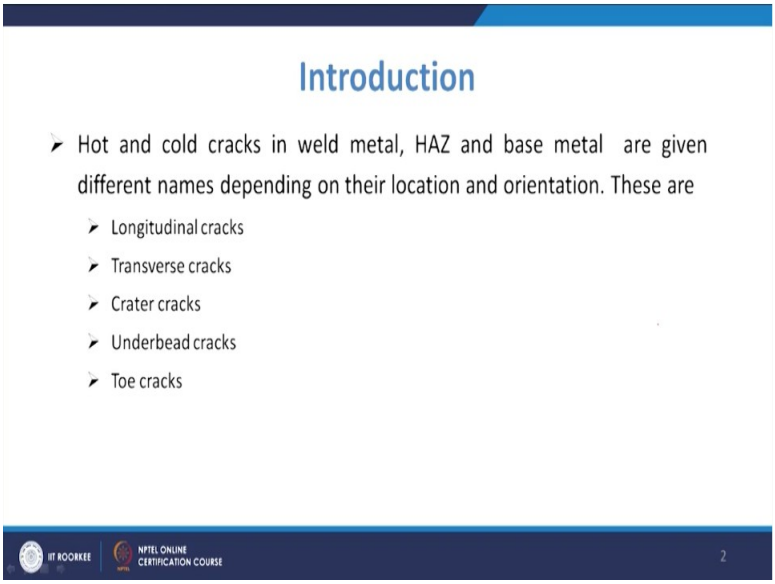

So, hot and cold cracks in weld metal, and HAZ and base metal are given different names depending on their location and orientation. So, you have these cracks only, but they may be in the weld metal, they may be in the HAZ or they may be in the base metal and they can be given the different names, where they are located, how oriented they are. So, these are normally, depending upon their orientation, you have the longitudinal cracks or transverse cracks.

Then you have the crater cracks or underbead cracks and then you have also toe cracks. So, longitudinal and transverse if you look at, they are depending upon the orientation that how they are oriented. Similarly, crater cracks will be because of the crater position, then you are underbead and this toe, they are because of the positions and all that, their location. So, that way, you have these cracks and we will talk about these cracks in somewhat more detail in

this lecture.

So, coming to the crater cracks, so, basically we are talking about the weld metal cracks, and if you talk about the cracks, which occur in the weld metal, then in that category, we have the crater cracks, longitudinal cracks and transverse cracks. So, first of all, we will talk about the crater cracks. Now, crater cracks occur when welding is interrupted. So, basically this is welding is interrupted. So, they are usually star shaped and progress only up to the edge of the crater also known as the paw cracks.

So, if you look at the crater crack, so, this is typically the example of the crater cracks.

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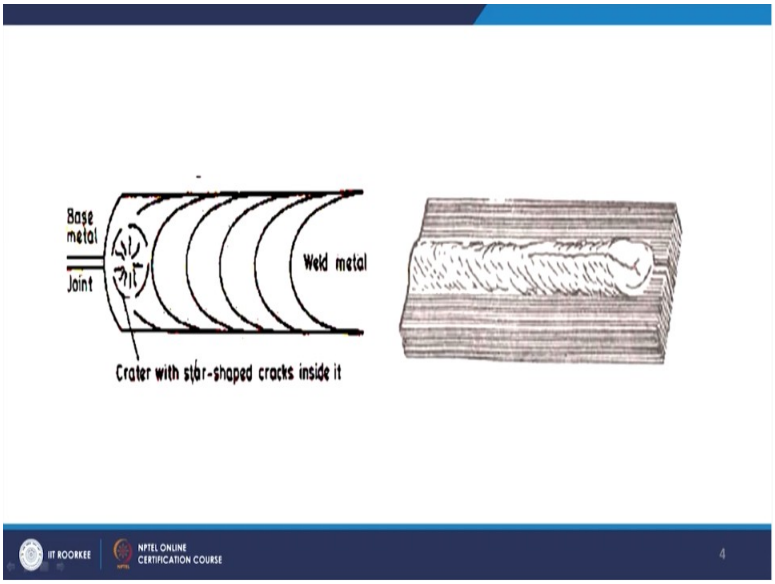

So, if you look at this C, this is the star shaped cracks, which is there insight and is the crater position. So, they are also known as the paw cracks because they resemblance is like the paw of the birds. So, that is why they are also known as the paw cracks. So, they are usually star shaped, so what you see is that they are usually in the shape of the star and then they will be progressing up to the edge of the crater. So, normally that is the, trait of these crater cracks.

So, these cracks basically their attribute is that they are many a times, they are the starting point for longitudinal cracks about which you see that is how they will be starting. So, normally, you will have the end cracks defined like this. So, they are basically they are starting points for the longitudinal cracks. So from here, these longitudinal cracks basically will be moving. So, here actually this is going towards the end, so, that is your end crack.

So, this crater crack will be extending into this weld metal and this becomes a longitudinal crack. So, that is what this figure shows. So, what is happening, in the crater cracks, what you see here, either you have the paw shaped, star shaped cracks what you see here, this results into the formation of these longitudinal cracks. So, normally these crater cracks will be started when you are stopping somewhere and then further you are restarting.

So, in those cases, you will have the appearance of this star shaped cracks. Now, they are normally found when, so, if you talk about the formation of these crater cracks, so, they are frequently found in the weld metal that has high coefficient of thermal expansion.

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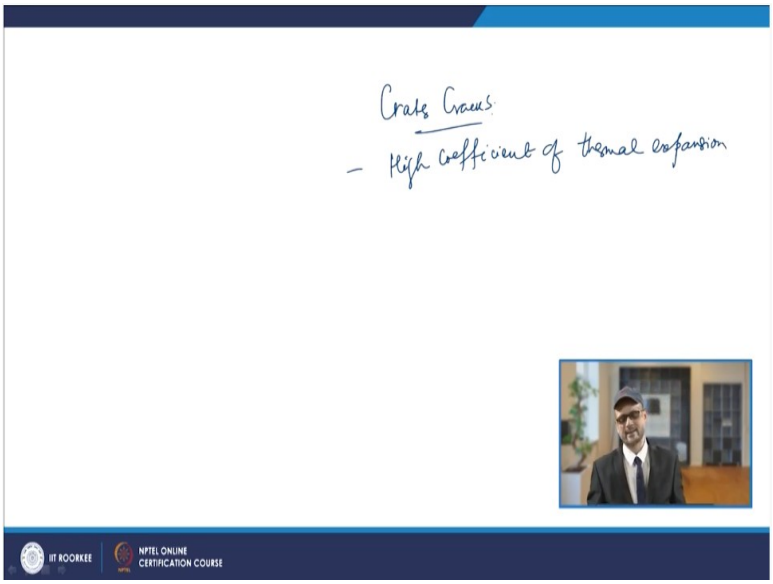

So, normally when you are welding any material which has very high coefficient of thermal expansion like austenitic steel, so, in those cases, your crater cracks are very likely to be found.

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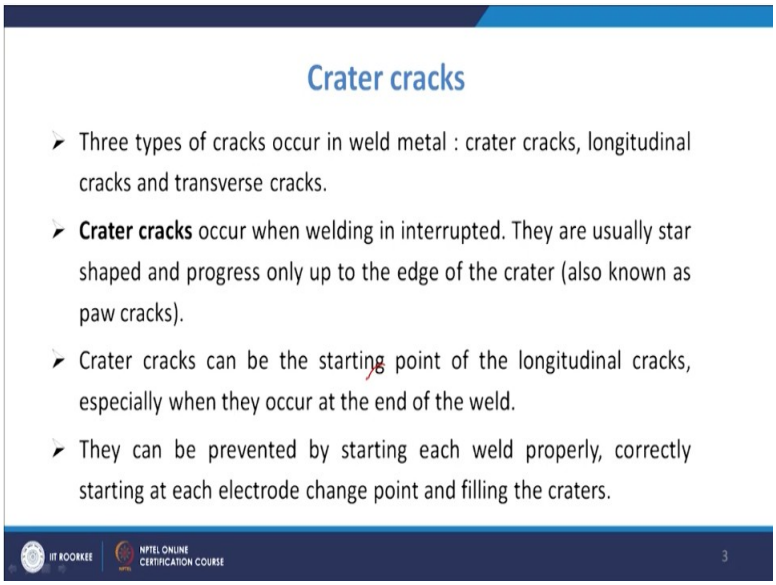

Now, we have discussed about the crater cracks and they can be prevented, so, what to see these cracks, so they are basically prevented, by starting the each weld properly because, they are likely to occur, because, your electrode is ending and then you are taking another electrode, so, at that point it is likely to start so, basically at that point, you must do something to fill those crater points. So, that is how you can prevent the formation of these crater cracks.

Coming to another type of crack, so another crack is the longitudinal weld metal cracks. Among the weld metal cracks, as we have studied we have 3 types of cracks, we have the crater crack, you have longitudinal weld metal crack, and you have the transverse weld metal crack.

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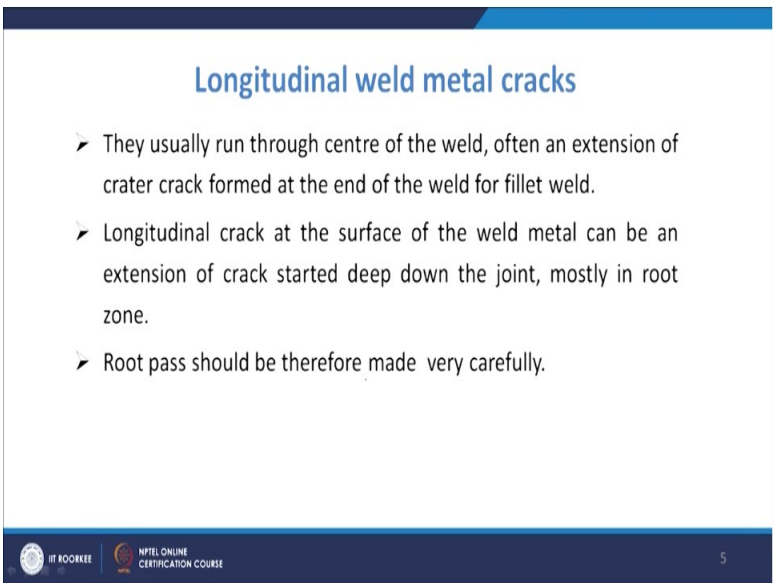

Now, the longitudinal weld metal crack, they usually run through the center of the weld, often an extension of the crater crack form at the end of the weld for fillet weld.

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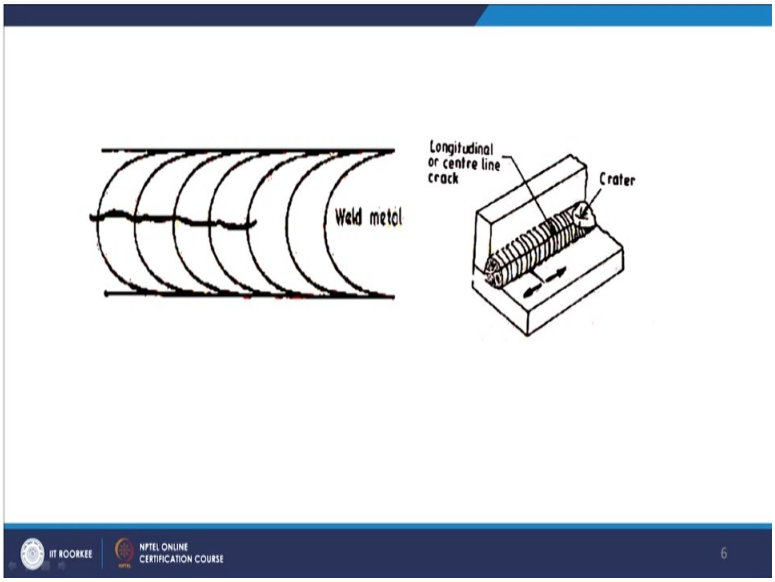

So, you can, you have a view of these fillet weld, so this way longitudinal crack looks like, so, normally and if your crack in the normal weld, so, this is the example of your longitudinal crack through the weld bead, so that is how it looks like. So, longitudinal crack at the surface of the weld metal can be extension of crack started deep down the joint mostly in the root zone. So, that is mainly, in that fillet weld where we have seen, so, here, in those cases, you can see, here it is seen that these longitudinal cracks.

Which are formed at the surface of the weld metal, so, they are the extension of the crack, which just started deep down that joint mostly in the root zone they start and then they move longitudinally, and that is how these longitudinal or centerline cracks are basically formed. So, the thing is that, you must have the proper, for that not to happen, your root pass must be made very carefully to avoid the formation of these longitudinal cracks. Then coming to another type of crack that is your transverse crack.

So, as we know, that, if it is parallel to this bead, then it is the longitudinal crack and if it is in the perpendicular direction, then it is known as the transverse crack. So, if you talk about the transverse crack, these cracks run across the weld perpendicular to the weld axis. So, if you look at this transverse cracks, yesterday also we discussed, so, this is how, this is your weld axis.

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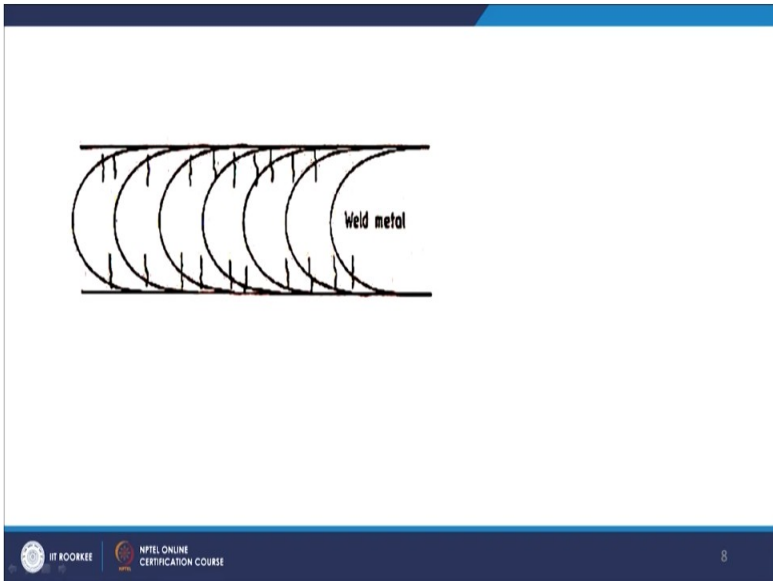

So, these cracks will be normally running so, they are across this or perpendicular to the weld axis their movement is.

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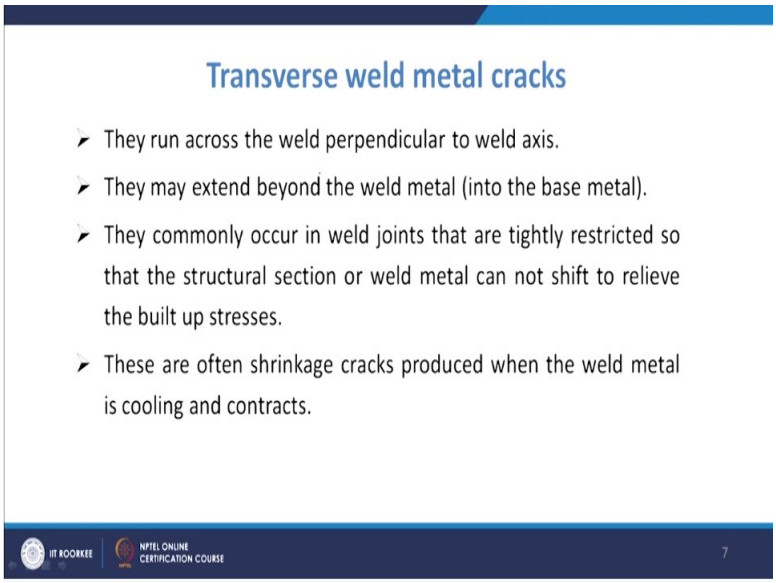

In many cases if you see, they may extend beyond the weld metal and they may go even into the base metal also. Also they commonly occur in weld joints that are tightly restricted, so, that the structural section or weld metal cannot shift to relieve the built up stress is what we have studied earlier that many a times, when there is restriction imposed. So, then in that case, it is very difficult for the stress to be relieved. Now, in those cases, in those joints, where you have the tight restriction.

And there is no possibility of the movement for the accommodation of these stresses which are building up. So, in those cases, these transverse weld metal cracks, they are likely to

come. So, normally these are often the shrinkage cracks produced when the weld metal is cooling and contracting. So, that is what normally as we have seen that on the sides, you have the heating and then further cooling and if you have the restraint on the sides, in those cases, these restraints will build up the stresses.

And those stresses if they are reaching beyond certain limit, beyond the strength of the material that condition, then in those cases, you have the possibility of having, the transverse weld metal cracks. So, this is the example of the transverse, this is the figure for the transverse weld metal crack. Now, we will come to the base metal cracks. Now, normally we have talked so far about the weld metal cracks, now, we talk about base metal cracks. So, normally they will be occurring in the base metal, usually located in HAZ and run parallel or perpendicular to the weld beat.

So, normally, they occur mostly when the HAZ becomes hard and brittle.

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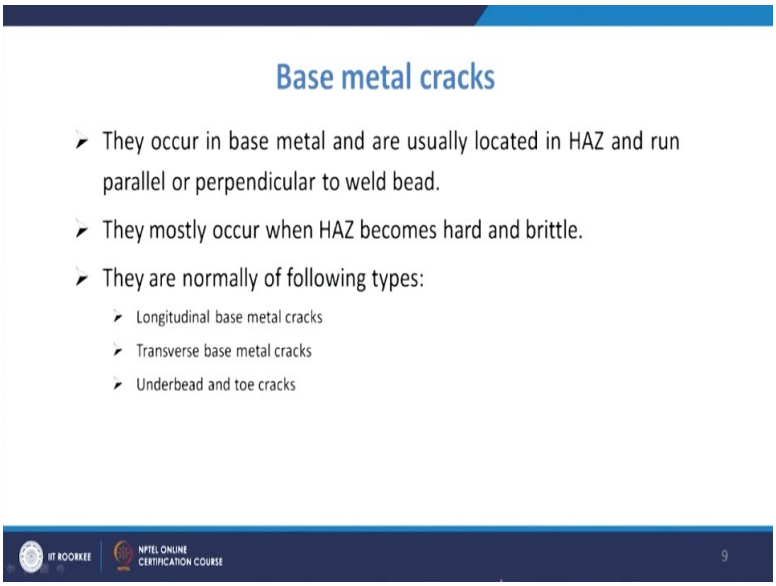

And that may be because of many reasons and so you have the existence of these different types of base metal cracks and they are of different categories like you have the longitudinal base metal cracks, you have transverse base metal cracks, you have the underbead or toe cracks, that is what normally is because of the positions where they are occurring. So, if you talk about the longitudinal base metal cracks.

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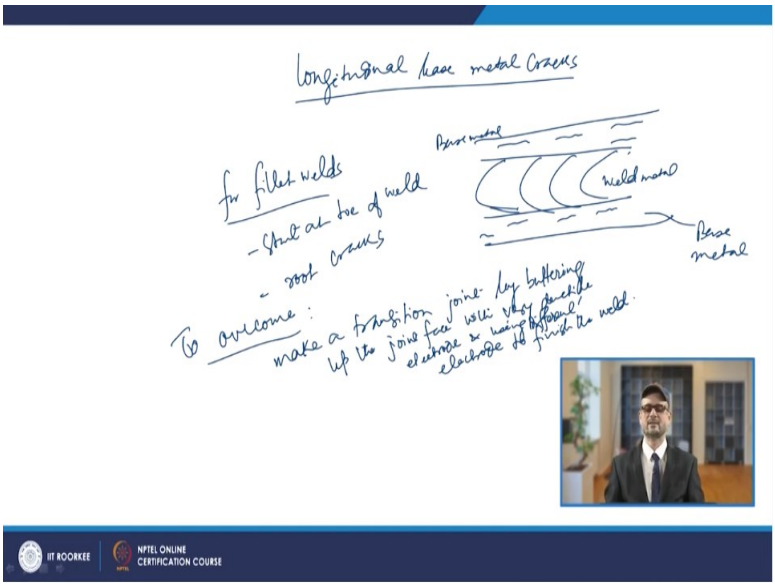

So, as you have seen that you have longitudinal weld metal cracks that will be in the weld bead, but, in these cases, these longitudinal base metal cracks, so they will be parallelly running to the weld and they will lie in the base metal basically. So, what is happening, so, there they will appear like so, if suppose, you have the weld bead appearing like this and this side you are base metal is there and this is your weld metal and this side is base metal.

So, in that base metal, you have cracks appearing like this, so, this type of cracks, which is there in this base metal zone, so they are known as the longitudinal base metal cracks. So, basically they are formed as extension of these boundary line cracks and this is due to the poor weld metal penetration into the sides of the butt joint. So, if you talk about the fillet weld, so for fillet welds, these, longitudinal base metal cracks, they are divided into 2 groups.

And one is that, which start at the toe of the weld, and another is that root cracks, which proceed from the root of the fillet weld. So, depending upon their position you have, either the are starting at the toe of the weld or which proceed from the root of the fillet weld and they go into the base metal and sometimes they even go out of the other side of the joint also. So, that way you have, the significance of these longitudinal base metal joints.

Now, in the case of, if you talk about these longitudinal base metal cracks, so, if you talk about, the butt weld, crack which is there in the base metal, they are likely to show up in the heat affected zone at the very edge of the fusion zone, and between the weld metal and the HAZ. So, there its presence can be seen. Now, this can be attributed to the hardenability property of the steel.

So, wherever you have steels with higher hardenability, that is what we have studied earlier. So, in those cases, they are more likely to be seen, because that cannot accommodate the stresses and in those cases, the cracks are likely to be seen, so, you should have the proper combination of the weld metal and the filler metal, so basically that hardenability basically you have to avoid.

So, what we do normally, to avoid the formation of these longitudinal base metal cracks to overcome this many a times what we do is we make a transition joint by buttering up the joint face with very ductile electrode and using different electrode to finish the weld. Because, in that case**,** there is ductility induced in that case, it is likely that there will not be occurrence of this kind of defect, that is your longitudinal base metal cracks. Then comes the transverse base metal cracks.

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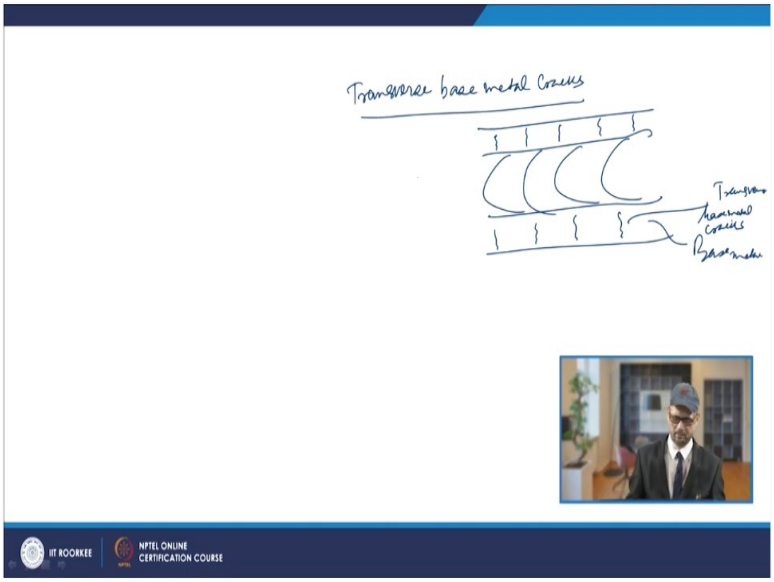

Now, here also similar to the longitudinal base metal cracks, in that case, you have the cracks seen in the transverse direction, so again you will have the weld beads, weld metal zone and in this base metal zone, you have the cracks, which will be seen like this. So, this shows the transverse base metal cracks. So, they are developing perpendicular to the weld axis. So, as you see that this is developing perpendicular to the weld axis.

And normally they are associated with the welding of high hardenability steels. So, normally when you do the welding of tool steels or certain alloy steels which are highly hardenable, in those cases, this kind of defects like transverse base metal cracks may occur. Now, they may

not be seen until the weld metal has cooled to the room temperature. So, many a times you need to do the nondestructive testing methods to see that.

So, what is happening when it is cooling and then after that you do the nondestructive testing like x-ray or many other nondestructive testing methods. So, only using those methods you will be able to see these transverse cracks in the weld bead or in the welded specimen.

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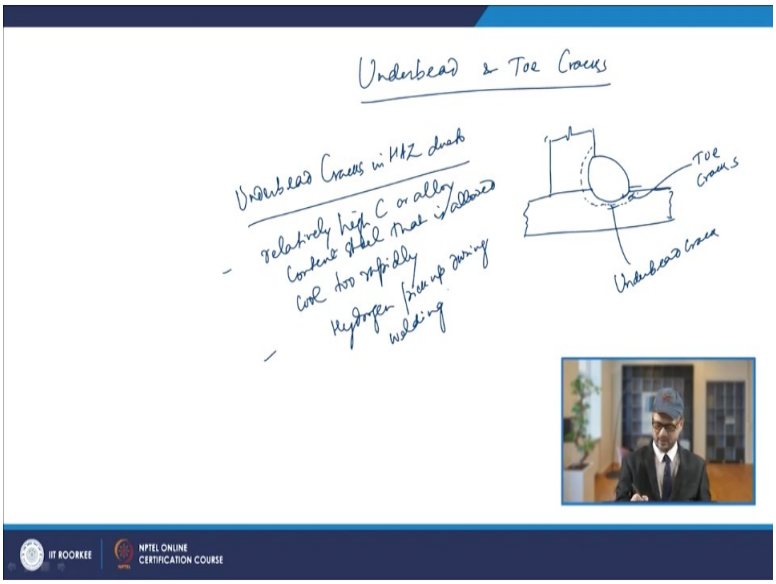

Then depending upon the location of the cracks, you have another category of the crack that is your underbead and toe cracks. So, these cracks **so**, they are the surface cracks in the base metal and they are under or near the weld. So, when they are, the surface cracks in the base metal under or near the weld, so that is known as the underbead cracks. So, we had seen yesterday this is your weld bead looks like and you have fillet weld, typical fillet weld will be shown like this.

And on this side, you have another plate. So, this way you have the plate which is there on this side. Now, in these cases, so you have the definition of the underbead cracks. So, when it is occurring below that bead, here, so, that is the example of underbead crack and then, similar cracks if they appear on the plate surface adjacent to the weld, so, if they are appearing here, adjacent to that weld, so then these cracks are known as the toe cracks.

So, if you talk about the reasons for the underbead cracks, so, if you see the underbead cracks, which are formed in the HAZ, they are due to following factors like when you have relatively high carbon content or alloy content steel that is allowed to cool rapidly. So, when

you have high carbon content or high alloy content and if it is allowed to cool very rapidly, in that case, there is chance of having the formation of undesirable structures.

So, that leads to the formation of these underbead cracks in the weld. And then, the other reason is the hydrogen pickup. So, these are the 2 reasons for the underbead cracks. If you talk about these 2 cracks underbead cracks or the toe cracks, they will be seldom appearing with certain steel compositions like, when the carbon is between point 0.06% to 0.25% or the manganese also has 0.35% to 0.8%. So, there is percentage range through that range basically these underbead or toe cracks seldom happens.

So another factor which is promoting these underbead cracking, one is the relatively high carbon or the alloy content, another is the hydrogen pickup, so, that is basically pickup and retention of the hydrogen, so if it is retained. So in those cases, you have these chances. So, basically that factor has to be kept in mind so that you must have the method, so that these hydrogen which is there, they should get the sufficient time to escape out of the weld.

So, if the cooling is basically rapid, in that case this hydrogen does not have enough time to go out and they are trapped in the HAZ and in that case, it will be creating a condition of low ductility type of condition and that is also known as the hydrogen embrittlement. So, that is basically the process of having hydrogen embrittlement because of these conditions of welding in which the hydrogen does not have enough time to come out.

Next thing what we can think about to avoid these type of defects is that you should go for slow welding or you may go for preheating, because, one is that, if you go for the slow welding, in that case, it is getting time, the hydrogen is getting time to come out. So, one way is that and another is that you can go for the preheating. So by doing the preheating basically, you are decreasing that cooling rate.

So, that also reduces the chance of formation of the undesirable structure or hard faces and that also reduces the chance of these underbead and toe cracks. So, when you have weld with large cross-section, they require higher heat inputs than the smaller ones, so, what you do is we give high welding current and slow welding speed. So, that reduces the rate of cooling and then that decreases the likelihood of the underbead and toe cracking.

So that is normally the cases with the formation of the underbead and toe cracks. Certainly, you have many other conditions also many other parameters are there like, you have other welding conditions are there, then joint also will be affecting. So what kind of joint is there, how much thickness of the metal is there, so, that way, that will also be affecting the amount of heat transfer that has to take place sideways.

So, all these in a compounding manner affect the likelihood of these underbead and toe cracks and accordingly you can have the proper way to control it. So, that is about underbead and toe cracks. Thank you very much.