Weldability of Metals
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Lecture-13
Weldability of Carbon and Alloy Steel-II

Hello, I welcome you all in this presentation related with the subject weldability of metals and we are talking about the weldability of the carbon and alloy steels, as we have seen that there are various types of the steels and which includes like carbon and low alloy steel, high strength low alloy steels quenched and tempered steel hardenable and heat ability steels and then there was the chromium molybdenum steel and the precoated steels.

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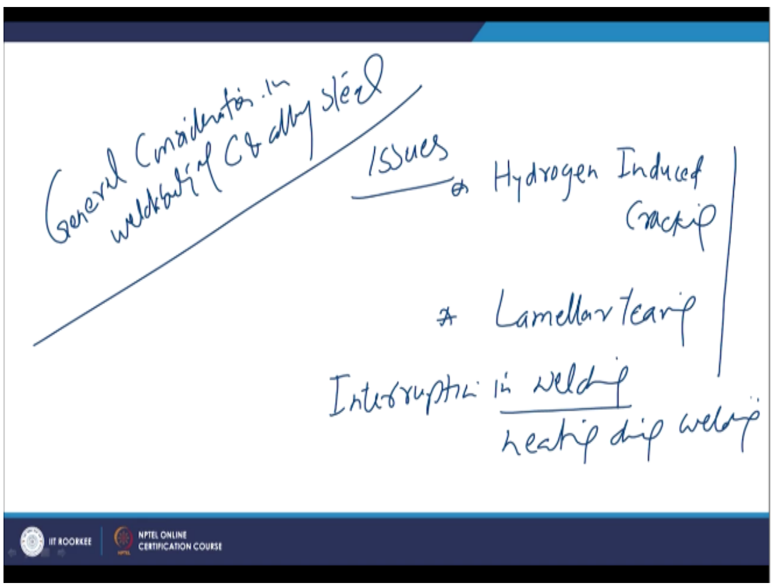

So we are starting our this chapter this presentation with the weldability of the carbon and low alloy steel. So it basically includes the general considerations related with the weldability general considerations in weldability of carbon and alloy steel or consideration visually includes the kind of the issues which are experienced in the welding of the carbon and alloy steels.

So depending upon the extent up to which these issues are encountered during the welding that determines the ease of welding, greater the issues, lower will be the weldability. So the common the most common problems encountered during the welding of carbon and alloy steel includes the hydrogen induced cracking. So this is one and the second one is basically lamellar tearing while other problems like the porosity and inclusions are also there.

But they will be triggering the cracking in one or other forms in addition to these 2 issues the problems are also imposed due to the interruption in welding, more primarily interruptions in heating during welding. So what kind of the interruptions which will be a occurring in which way it can affect the ease of welding or it can create the issues associated ah with the welding.

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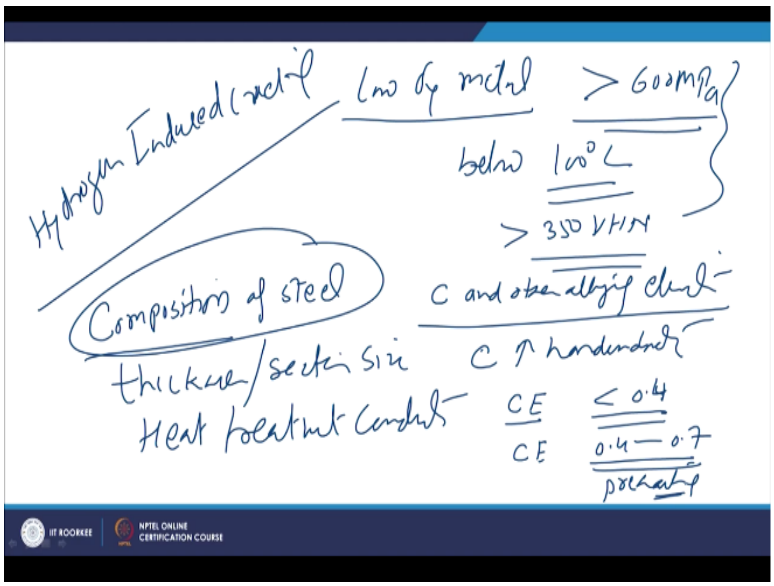

So we will start with the hydrogen induced cracking normally the hydrogen induced cracking is not observed in case of the low yield strength metals or low in strength steel. So the yield strength of the steel is greater than roughly 600 MPA, then the steels become sensitive for hydrogen induced cracking and especially it occurs at temperature below 100 degree centigrade.

So these are the 2 bigger points especially in the hardness when the hardness is greater than 350 vhn and so these factors will be giving us the rough idea about the kind of the steels which will be sensitive for hydrogen induced cracking and if we see the kind of tendency for the hydrogen induced cracking is influenced by the composition of the steel which is being considered it is the thickness section, section thickness or thickness of section size heat treatment condition.

And among these the most important factor is the composition of the steel and this the steels which are primarily comprises the carbon and other alloying elements, so a carbon directly increases the hardenability to account the effect of other alloying elements similar to that of the carbon basically a parameter called carbon equivalent is considered or it is calculated. So when the carbon equivalent is calculated it gives us idea about the kind of the hardenability which will be shown by a given steel.

And that intern determines the ease of welding or the weldability, so for carbon equivalent when it is less than 0.4 then the weldability is considered to be good when the carbon equivalent in the range of 0.4 to 0.7 the weldability is considered to be fair because it is facilitated with the help of the preheating, preheating is needed of the wearing degree or different levels and if the carbon equivalent is greater than 2.7 then the weldability is considered to be poor.

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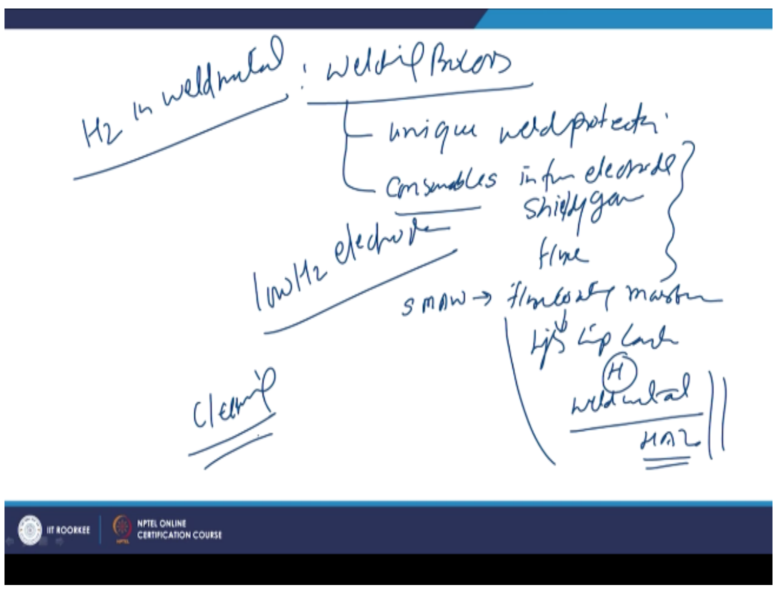

And that requires extreme care to facilitate the welding, so as far as the hydrogen induced cracking is concerned they are 3 important aspects to be present for which will facilitate the occurrence of the hydrogen induced cracking these include like the favourable microstructure and which is basically the presence of either martensite only or the presence of martensite and the ferrite in the matrix of the steel.

The second one is the presence of the tensile residual stresses, so this is commonly encountered during the fusion welding and it is observed in the weld metal as well as the heat affected zone then third important aspect which needs to be there for occurrence of the hydrogen induced cracking is the presence of hydrogen content in the Hz or in the weld metal. So these are the 3 factors that need to be there for the occurrence of the hydrogen induced cracking.

So where from the hydrogen will be coming in the weld metal, we know that the different welding processes, different fusion welding processes are there is welding process offers unique weld protection level or quality or the degree of protection is different to which is associated with each process. So like shielded metal arc welding process offers the lower protection as compared to the gas tungsten arc welding process or the plasma arc welding process or the gas metal arc welding process where inert gases are used.

Then the kind of the consumables which are used like the few consumables are like a low hydrogen consumables where either no moisture is present or the no hydrogen is there in any of the form. So a consumables in form of electrode or the shielding gases or the fluxes. So these will be the another aspect the kind of the consumables which are being used whether they are free from the hydrogen or not, invariably in the electrodes which are used in the shielded metal arc welding they use the flux coating which absorbs the moisture.

So this moisture under the arc condition or high temperature conditions this moisture breaks down into the atomic hydrogen which is absorbed by the weld metal and due to the higher cooling rate it is retained by the weld metal as well as the heat affected zone. So the hydrogen which gets dissolved at a high temperature does not get enough time for escaping and that remains with the weld metal as well as the heat affected zone.

So if the hydrogen is coming from any of the sources then that will be leading to the presence of the hydrogen in the weld metal and that is why the metal system or steels which are sensitive for the hydrogen induced cracking we prefer the low hydrogen electrodes. So that the hydrogen is not provided by the welding consumables which are being used for this purpose. Apart from this the kind of the cleaning which is being used or the extent of the cleaning or the surface preparation is being done.

How properly the surface preparation is being done to ensure that the faying officers are free from the oxides impurities, moisture, the grease, oil, paint extra. So subsequently these impurities in the arc environment do not provide the hydrogen to the weld metal. So that the weld metal remains free from the hydrogen and the second aspect is the microstructure aspect that is leading to the martensite formation.

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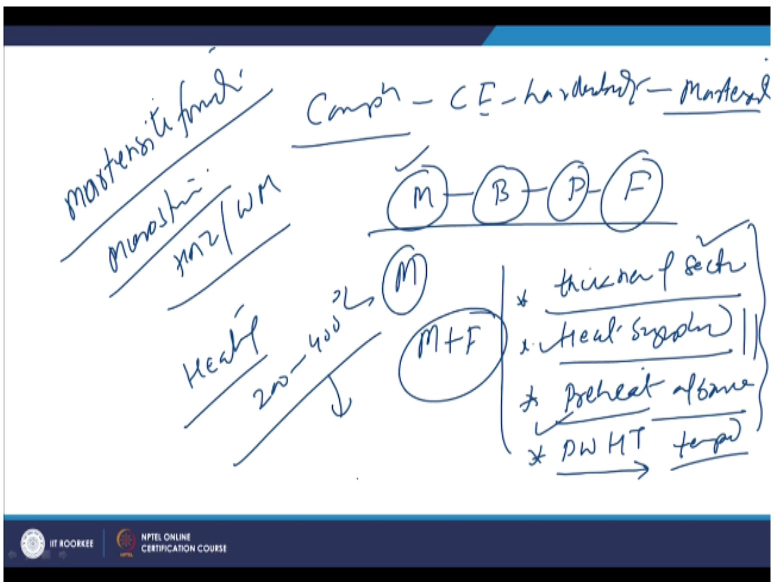

The martensitic transformation is directly linked with the composition of the steel, if the steel is of the high carbon equivalent it will show the higher hardenability and which will show the increase the tendency for the martensite formation. So the steel if the steel microstructure of the steel being formed either in the heat affected zone or in the weld metal if it is having the martensite or bainide or pearlite or ferrite.

Then this is the sequence of the microstructure in decreasing order of the hydrogen induced cracking tendency, maximum hydrogen induced cracking pregnancy is observed in case of the martensite and then somewhat lower tendency in case of the bainide, then pearlite, then ferrite. So mostly most sensitive is martensite and martensite+ferrite mixtures are also found sensitive for the hydrogen induced cracking.

And which phase will be formed which kind of the structures will be form that is affected by the section thickness, thickness of the plate or the section which is being welded because it determines the kind of the heat that is to be supplied for the welding purpose greater the thickness faster with the extraction of the heat from the weld metal, on the other hand it will require the greater heat inputs.

So heat input in turned higher heat input intern reduces the cooling rate. So in order to have the cooling rate within the safe limit so that undesirable structural transformations are avoided we use the controlled preheating of the base metal during the welding, so that the safe cooling rate is maintained in the weld metal as well as heat affected zone in order to avoid the undesirable martensitic authority martensitic transformations.

In addition to the heat input and the preheating if the martensite has been formed and still if you want to control the undesirable effects associated with the hydrogen induced cracking then sometimes post weld heat treatment is also carried out. So that the martensite can be tampered and also the hydrogen which has been trapped can be eliminated or can be reduced in which was dissolved in the weld metal as well as heat affected zone.

So normally the heating of the weld in the range of like 200 to 400 degree centigrade helps in diffusion of the hydrogen from the steel, so that escaping of the hydrogen from the weld as well as heat affected zone can be facilitated in order to avoid the undesirable effects as related with the hydrogen induced cracking.

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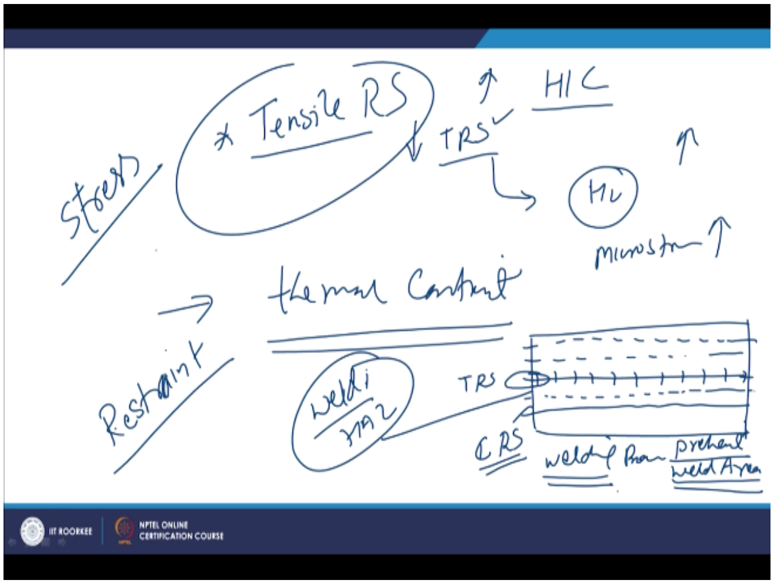

Then the stress is the another important aspect that has to be there to facilitate the hydrogen induced cracking and other the these stresses are if these are of the tensile in nature, tensile residual stresses, then it will be promoting the hydrogen induced cracking tendency significantly. So all those steps methods which can be applied in order to reduce the magnitude of the tensile residual stresses that will help in reducing the hydrogen induced cracking tendency.

Because the stress magnitude required for hydrogen induced cracking is directly influenced by the hydrogen concentration in the weld metal as well as the kind of the microstructure it has greater the hydrogen concentration and harder micro constituents in form of martensite is present in the greater fraction of the martensite is present then that will be reducing the stress required for hydrogen induced cracking.

So if we can apply the methods like shot peening or shot blasting or the post weld heat treatment which will help us in reducing the tensile residual stress magnitude then that will certainly help in reducing the tendency for the hydrogen induced cracking where from this that tensile residential stresses or residual stress development in the weld join come in so the factors that affect the residual stress magnitude being developed is the welding is the thermal contraction.

This is the main source of the residual stress development because localized heating of the plates during the welding causes the localized expansion and subsequently on cooling the contraction is facilitated but the contraction is not complete, so left out strain due to the reduced thermal contraction leads to be logged in strain and that in turn leads to the development of the tensile or the residual stresses.

So wherever the maximum contraction is restricted that occurs that maximum contraction restriction is observed in the weld zone, so this experience is the maximum tensile residual stress while in the zone in vicinity of the weld metal will also be having some amount of the tensile residual stresses and there after the balancing ledger balances is also developed which will both the sides of the weld metal and these will be inform of the residual compressive residual stresses.

So in light of this if we noticed the weld metal and the heat affected zone in vicinity of the weld metal will be most sensitive for the hydrogen induced cracking due to the presence of the tensile residual stresses there, then the degree of restraint during the welding which is present also affects the residual stress magnitude, higher the degree of restraint and ah welding is being performed under more strict fabrication conditions where the movement of the plates being welded is very limited or its is absent.

In that case the resistance the magnitude development of the resistance will be more, then the welding procedure also affects the residual stress being developed, welding procedure which includes like preheating greater is the amount of preheat lower will the residual stresses, then the groove preparation or edge preparation, so that will be affecting the weld area or the volume of the weld metal been deposited.

In general greater is the weld metal volume, greater will be the residual stresses due to the increase the magnitude of the contraction expansion and contraction, so the regular is magnitude in general increases with the increase of the weld area, then the sequence in which heat is being applied if the welding is being done in single pass then it will be leading to the development of the maximum residual stresses.

But if the welding is being done in sequence in such a way that the earlier developed residual stresses are eased out by the subsequent applications of the heat during the welding then that can help in reducing the residual stress development during the welding.

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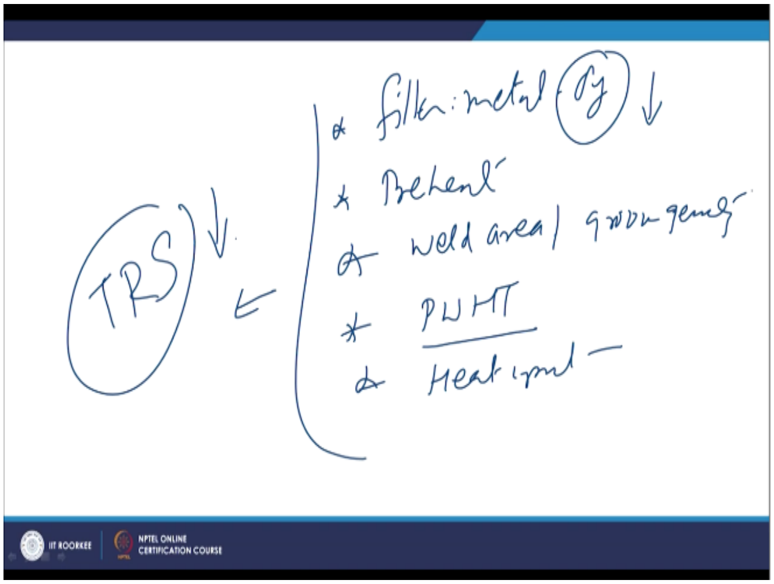

So the important factors that affect the resistance magnitude includes like the filler yield strength, maximum residual stress magnitude can be equal to the yield strength and if it is more than that then the residual stresses will be released through yielding or the deformation of the metal then the kind of the preheat greater is the preheat, lower is the residual stress.

So in order to reduce the residual stress sometimes we use the filler metal of the lower yield strength then preheat and then the weld area which is being influenced by the groove geometry being used for development of the weld joint and then the post weld heat treatment, then the heat input kind of heat input which is being game and if we control these aspects appropriately then the residual stress special tensile residual stress development can be reduced to a great extent.

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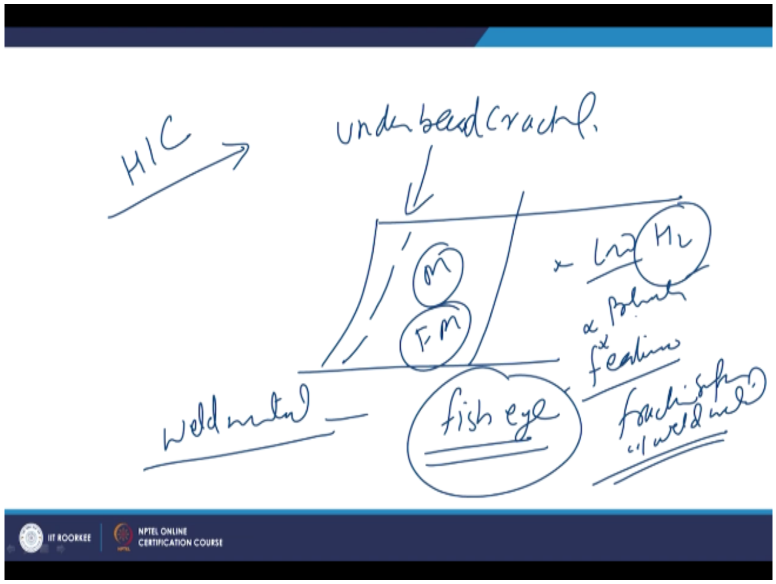

And that intern will help in reducing the hydrogen induced cracking tendency, then we have the most common form in which the hydrogen induced cracking observed is the under bead cracking. Under bead cracking is mostly observed in next to the fusion boundary in the base metal, so the cracking which is occurring next to the fusion boundary in the heat affected zone is mostly considered as under bread cracking been triggered by the hydrogen induced cracking.

And this is promoted by the martensite transformation or the ferrite and the martensitic transformation, then the cracking which occurs in the weld metal this is observed typically in terms of the fish eye, this kind of the fish eye is the kind of the typical feature which is observed on the fracture surface of the weld metal which has failed due to the embrittlement promoted by the hydrogen,

So the hydrogen induced cracking in weld metal is being is appearing in form of the fish eyes especially on the fracture surface which is developed after the suppression of the component from the weld metal. So in order to control the weld metal cracking basically the low hydrogen electrodes we can use and we can also do the preheating of the base metal. So that the weld metal gets enough time for the solidification.

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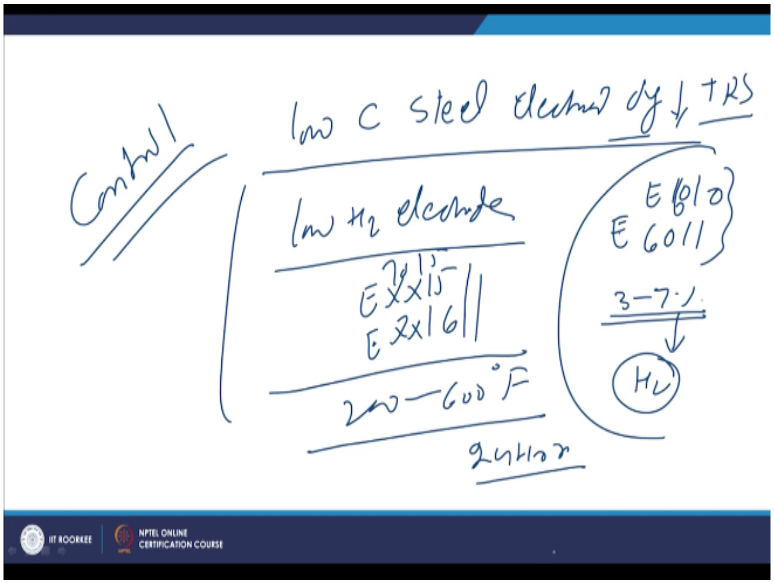

And then the post weld heat treatment by prolonged exposure at elevated temperature of the entire weld joint helps in skipping of the hydrogen from the weld metal. So for control what are the things that we have at our end is the use of the low carbon steel electrodes. So our yield strength is less which will be reducing the tensile residual stresses as well as will be facilitating easing out or making the weld metal more commodity for the locked in strains.

If we take the low hydrogen electrodes that will further reduce the tendency for the presence of the hydrogen in the weld metal, say for the electrodes like 1 0 or 6 0 1 6 0 1 0 and 60 11 these electrodes are cellulosic and have offer the moisture content of 3 to 7% and the high moisture associated with such kind of the electrodes leads to the very high at concentration of the hydrogen in the weld metal and thereby these promote the hydrogen induced cracking.

So instead of using the such kind of the electrodes it is better to use the low hydrogen electrode, so that the cracking tendency of the weld metal can be reduced in the typical hydrogen electrodes includes like 6000 to 7000 series like 15EXX16, so these are the 2 common low hydrogen electrodes of either 7000 or 6000 7015 or 6015, those kind of the electrodes can be used and thereafter the exposure of the weld joints in the range of 200 to 600 degree Fahrenheit ah for 24 hours helps in skipping of the hydrogen.

So that the issues related to the hydrogen induced cracking tendencies can be attached to some extent, another problem which is commonly observed during the welding of the carbon and alloy steel is the lamellar tearing.

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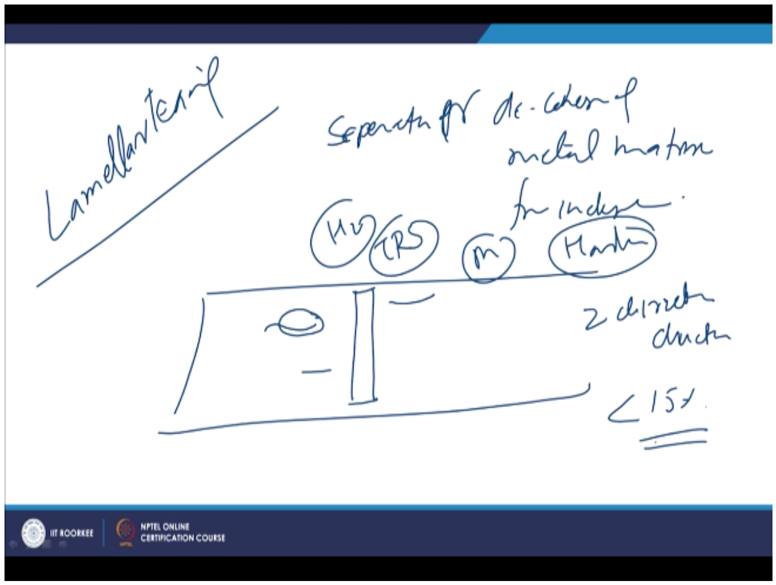

Lamellar tearing is basically about the separation or decohesion of the metal matrix from inclusions so like a steel having the inclusions like this, so these inclusions get separated from the matrix about it is promoted by the presence of the hydrogen tensile residual stresses hard martensitic structure, high hardness as well as the Z direction ductility . This is basically the ductility of the metal in the thickness direction.

So the metals having the Z direction ductility less than 15% are found to be sensitive for the lamellar tearing, so and this type of the tearing is typically observed in case of the groove weld, fillet weld and in T joint configurations.

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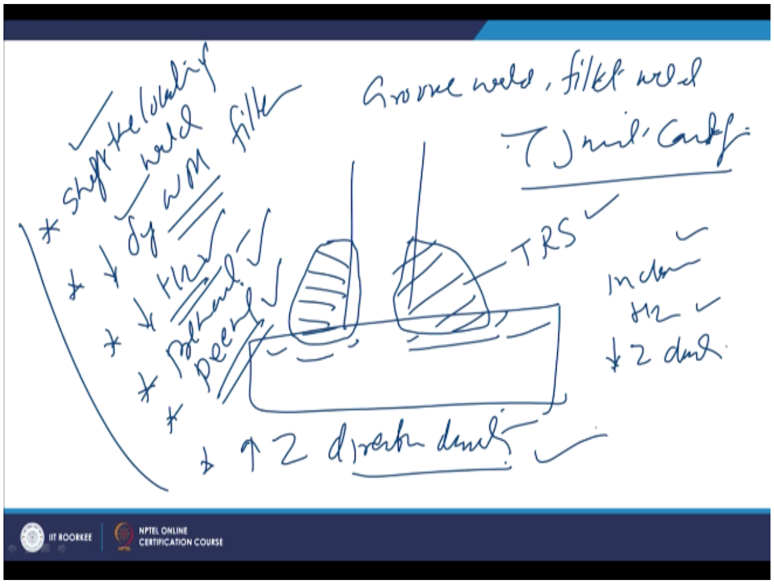

Like say joint is typically like this so the development of the weld this manner will be setting up of the higher residual stresses in the weld zone, so due to the shrinkage the setting of the tensile residual stresses will be setting up the metal next to the weld zone under the very restraint conditions and if there is a presence of inclusions as well as hydrogen and so the high tensile residual stresses inclusion, hydrogen as well as the limited Z direction ductility.

It will easily promote the cracks or the lamellar tearing in the region next to the weld metal and this kind of cracks will subsequently propagate into the base metal. So what basically we have to do is for controlling the lamellar tearing we can change or shift the location of the weld suitably so instead of having the fillet weld we can redesign the component so that instead of this kind of weld we have the butt joint configuration.

Then so simply shifting the location of the weld so that the residual stresses are redistributed in more favourable manner in order to avoid such kind of the cracking tendency as far as possible use the low yield strength weld metal. So use of the low yield strength filler metals will help in reducing the residual stress magnitude and which intern will help in reducing the tendency for cracking, reduce the hydrogen concentrations.

So this can be done through the use of the low hydrogen consumables or proper precautions during welding, so that the hydrogen in the weld metal can be reduced use suitable preheat so that increased reducing cooling rate and increase high temperature retention period helps in the skipping of the hydrogen from the weld as well as the heat affected zone, shot peening will help in releasing the residual stresses being developed.

And then using the base metal having the high Z direction ductility, so these are some of the steps which can be taken in order to avoid the possibility of the reduce the possibility of the lamellar tearing. So shifting the location of the weld reducing the using the low yield strength filler metals reducing the hydrogen concentration in the weld use of preheat, shot peening and the using the metals having the good Z direction ductility.

So these are the 2 most common types of the problems which are encountered during the welding of the carbon and low alloy steels. Now I will summarize this presentation, in this presentation basically I have talked about the hydrogen induced cracking, the various factors that promote the hydrogen induced cracking and what can be done to control the hydrogen induced cracking and thereafter another commonly encountered problem in welding of the carbon.

And low alloy steel that is the lamellar tearing, so what are the factors that contribute towards the lamellar tearing and what steps can be taken to avoid the reduce the tendency of the lamellar tearing, thank you for your attention.