Weldability of Metals

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Lecture-25
Weldability of Q & T Steels-IV

Hello, I welcome you all in this presentation related with the subject weldability of metals and you know that we are talking about the weldability of quenched and tempered steels. And so for about this steel we are talked about the chemical composition and the properties of the steel the kind of preheat which is needed for the welding of these steels. Then the welding processes and the heat input which is normally used for the welding of the quenched and tempered steel.

In this presentation we will try to talk about the technique which is to be used for welding of the Q and T steels like the way by which we deposit the metal during the welding. For example we are using either a stranger bead or viewer bead, so which type of weed is to be used that about that I will talk first. Thereafter we will see if at all there is a need of the post weld heat treatment then how the heat treatment is to be done of the weld joints.

And normally these weld joints are not subjected to the post weld heat treatment because generally they adversely affect the properties. So very in specific situations the post weld heat treatment of these steels is carried out.

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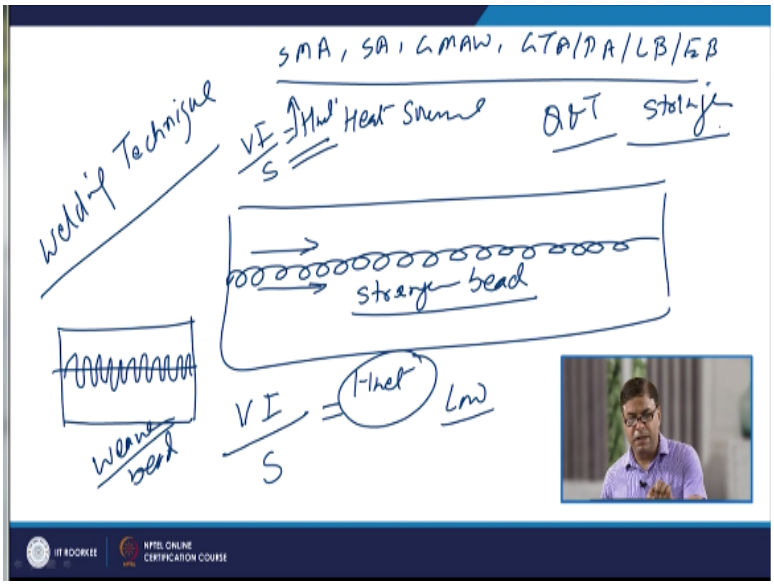

So, as for as the welding technique is concern like there can be number of processes which can be used for depositing the weld metal submerged arc welding shielded metal arc welding. Then gas metal arc welding and non consumable processes like GTAW and the PAW processes then laser beam and the electron beam welding processes. But metal is being applied and how the heat source is being applied during the welding.

So, during the welding if the metal is deposited by movement of the heat source along the weld line it is a straight line. Then it is a kind of the a stranger bead and when the stranger bead is **is** applied for development of the weld joints the movement in the direction of the welding is fast and therefore the net heat input for a given voltage and current setting when the speed of the heat source movement is high.

Then we get the net heat input that is H net is low, so low heat input is realized. On the other hand when we use the weaver weed, so in case of the weaver weed the heat source is moved is oscillated about the weld joint line like this. So, there are various possible movements which are used oscillation movements which are used means various patterns are there to oscillate the movement of the heat source during the welding.

So, that the more amount of the heat can be delivered, so when viewer bead is applied our actual the speed of the movement in the direction of the welding, speed of the movement of the heat

source in the direction of the welding is reduced in case of the weaver weed case. So, our net heat input is reduced, for a given current setting if the s is reduced then net heat input is increased.

So, the increased heat input deteriorates the weld joint properties especially the notch toughness and the strength. Therefore for the welding of the Q and T steels primarily we prefer to use the stranger bead as compare to the weaver bead.

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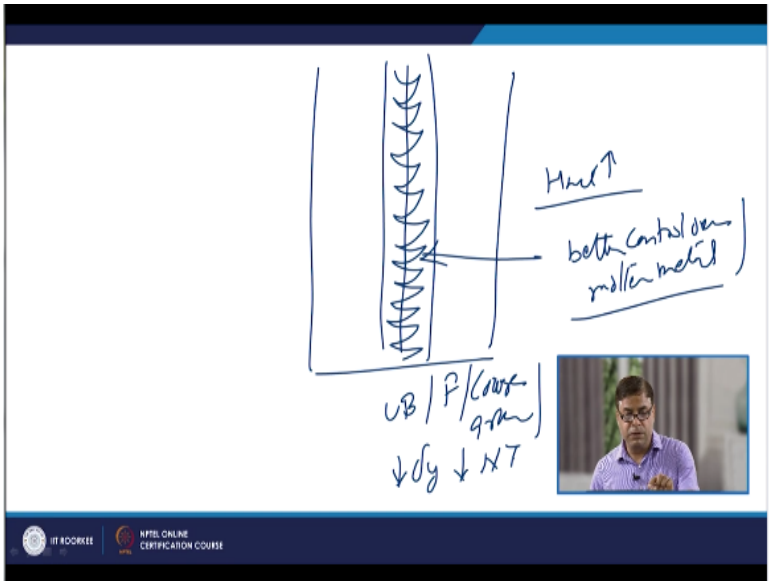

But sometimes it is required to use the weaver bead especially when the welding is carried out in the vertical plane. So, in order to have the better control over the movement of the molten metal while it is being deposited we give lot of the literal movement or oscillating movement to the heat source. And so in this process, so our H net becomes higher and it deteriorates the properties.

But the primary goal of oscillating the heat source here is to have the better control over the molten metal which is being deposited. So, these are the 2 techniques of applying the molten metal and of course when the weaver bead is used due to the high heat input we get the lower cooling rates upper bainide and the ferrite coarse grain structure. So, these deteriorate the yield strength these reduce the notch toughness of the weld joint.

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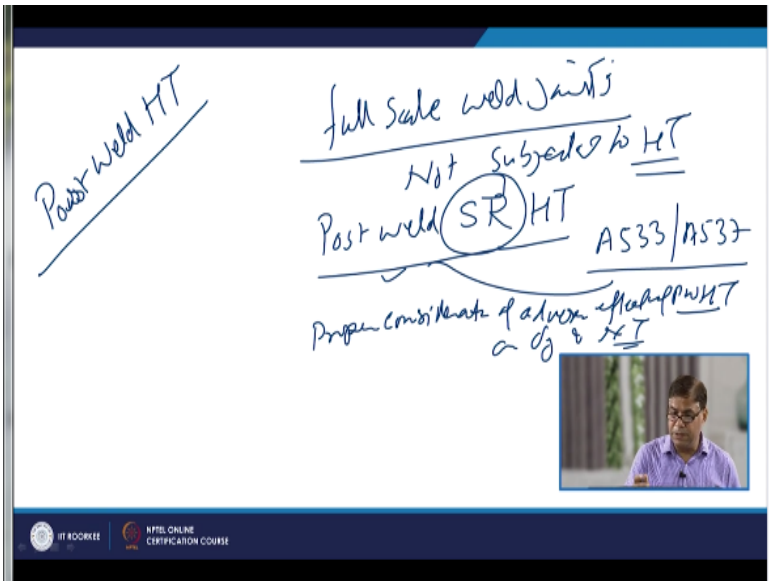

Now coming to the post weld heat treatment, normally the full scale weld joints are not subjected to the heat treatment of the Q and T steels, Q and T steel weld joints are normally not subjected to the post weld heat treatment. But they are certain types of the steels which may be given post weld stress reliving heat treatment and like A533, A537 steels under some circumstances.

They are given the post weld heat treatment n order to reduce the residual stresses but before giving any such kind of the stress reliving heat treatment proper consideration of adverse effects of the PWHT on the yield strength and notch toughness, this must be considered . So, that the joint mechanical performance of the joint is not compromised because of such kind of the post weld heat treatment.

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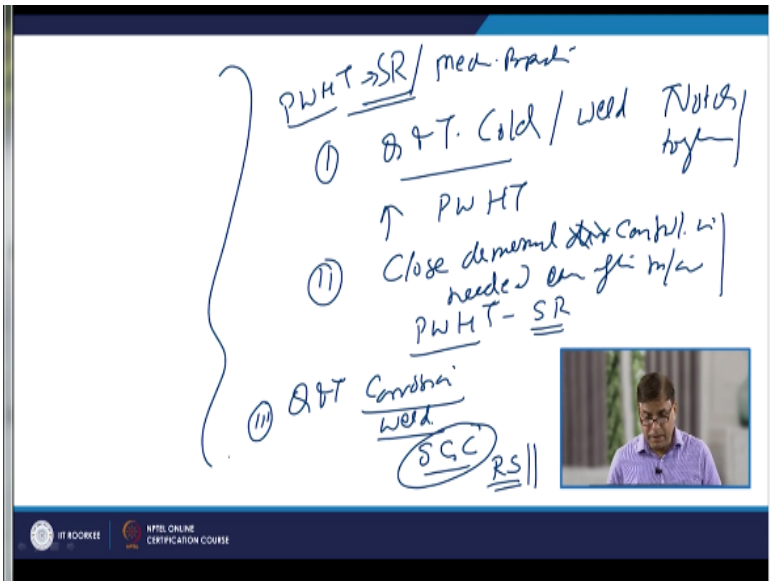

And the post weld heat treatment may be needed for reliving the post weld heat treatment primarily for reliving the residual stresses means stress reliving heat treatment is carried out for reliving the residual stresses or to achieve the specific set of the mechanical properties. For example the Q and T steel has been cold walked or after the welding it is toughness or the notch toughness has been badly compromised.

So, in order to induce the toughness in the Q and T cold walked steels or the weld joints which have resulted extremely high hardness and the lower notch toughness the PWHT may be needed. The second situation where post weld heat treatment maybe required is where like very close dimensional control is needed even after machining.

Because weld joints when subjected to the machining, so removal of the material relives some of the stresses and that leads to the dimensional variation and sometimes shape variation. So, if very close control over the dimensions are very good dimensional stability required after the machining of the welded joints. Then also the PWHT is given for stress reliving purpose, so that after the machining the required close control over the dimensions or the dimensional stability can be realized.

And if the Q and T steel is subjected to the operation or service in corrosive environment where the weld joint can experience the stress corrosion cracking due to the presence of the residual

stresses which are present in the weld joints. So, we need to relive the residual stresses in order to reduce the stress corrosion cracking tendency through the proper post weld heat treatment. So, these are some of the situations where post weld heat treatment of the Q and T steels maybe needed.

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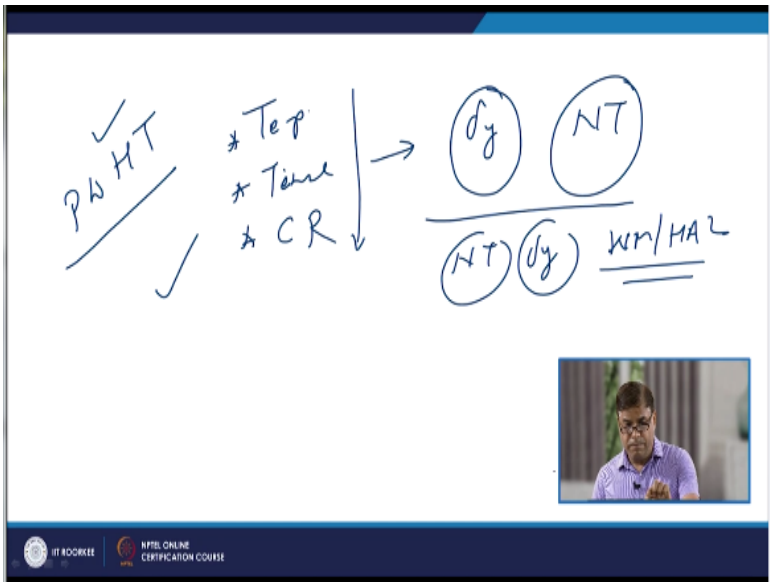

And whenever and when enlight of these requirements if at all we have to perform the post weld heat treatment. Then we need to establish the proper soaking temperature the time for which exposure we will be given and the after exposure the kind of cooling rate which will be imposed. So, that after identifying the time, temperature and cooling rate conditions for post weld heat treatment we need to investigate.

Whether the weld joint which has been subjected to the post weld heat treatment is having the set of the minimum accepted level of the yield strength and the notch toughness. So, the pose weld heat treatment need to conditions for the post weld heat treatment need to be established after thorough investigation of the coupons of the of that metal systems.

So, that after establishing the proper post weld heat treatment conditions the heat treatment can be given to the actual or the real weld joints. And these things are especially needed to restore the notch toughness and yield strength of the weld metal as well as Hz if these have been compromised during the welding of the steel.

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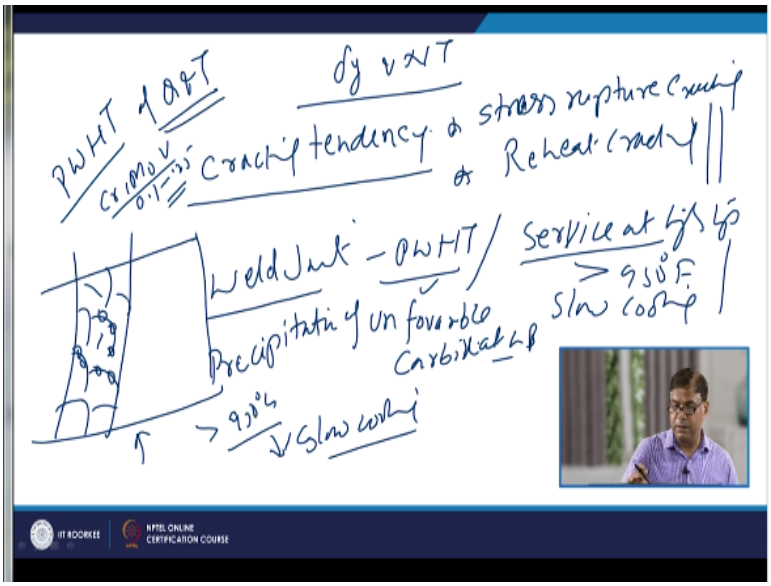

So, now apart from the as I have said there are so many adverse effects of the post weld heat treatment of the Q and T steels. So, that is why we need to be very careful that it does not adversely affect the properties. So, apart from the compromise on the yield strength and the notch toughness after the post weld heat treatments sometimes the Q and T steels weld joints after the post weld heat treatment show very much cracking tendency.

This cracking tendency is observed in form of the stress rupture cracking, this is also known as the reheat cracking. And then this kind of the crackings are observed when the weld joint of the Q and T steel given the PWHT heat treatment in a certain temperature range or the weld joint is subjected to the high temperature service at high temperature.

So, the temperature greater than 950 degree Fahrenheit followed by slow cooling. So, either after the welding or when exposure is being given for the stress reliving during the post weld heat treatment or the weld joint is given exposure at a high temperature during the service followed by slow cooling. These things lead to the so means this high temperature exposure leads to the precipitation of some unfavorable carbides at the grain boundaries.

Like say the steel in the weld joint or in the heat affected zone like this or in the weld joints. These steels frequently have the chromium, molybdenum, vanadium and also having the carbon

in range of 0.1 to 0.25%. So, when these steels are heated at a high temperature greater than 950 degree centigrade followed by slow cooling. So, these conditions favor the precipitation of these carbides.

So, the precipitation of the carbides at the grain boundary this disturbs the strengthening contribution being given by the grain and the grain boundaries. So, in this case grain boundaries are weak and due to the formation of these unfavorable precipitates as compare to that of grain and under the external service conditions these tend to show the cracking

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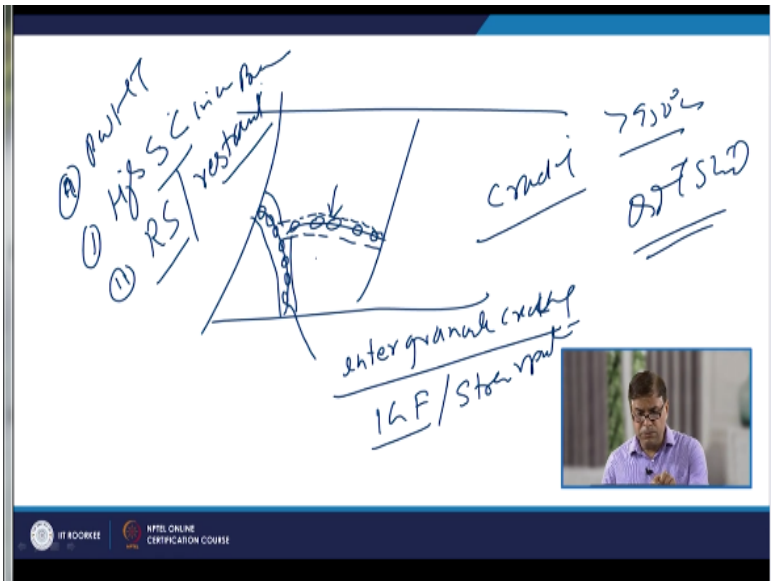

So basically since these this kind of the precipitation takes place at the grain boundary like say this is the heat affected zone. And here precipitation has taken place at the grain boundary and these boundaries**.** So, the grain boundary area is weakened, so the cracks start to propagate along the grain boundary because of precipitation of these unfavorable carbides especially at the grain boundaries.

So, inter granular cracking means cracking preferentially follows the path of the grain boundary. So, inter granular cracking takes place and it appears eventually in form of inter granular fracture or stress rupture. So, this is that kind of the cracking which is promoted by the high temperature exposure above 950 degree centigrade of the Q and T steel weld joints.

So, we need to be careful and this aspect must be investigated and this kind of the cracking is promoted especially in presence of when the high stress concentration is present in the weld joint or higher residual stresses are present or especially due to the high restrain welding under the high restrained conditions or unfavorable PWHT is been given.

So, unfavorable PWHT conditions the presence of the higher stresses or the welding under the restrained conditions**.** These promote first the precipitation and then propagation of the cracks preferentially along the weakened grain boundaries due to the precipitation of these unfavorable carbides.

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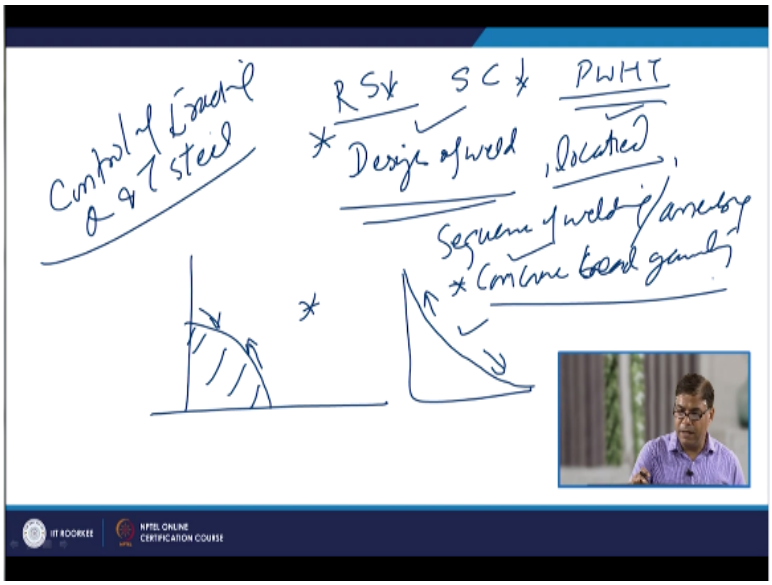

So, in order to control such kind of the cracking tendency control of the cracking tendency in the Q and T steels. We need to sure that residual stress magnitude is lowered, a stress concentration is lowered and PWHT conditions are properly established. And for that purpose we need to design of weld properly means which kind of the groove geometry will be used, what will be the volume of the weld metal.

And where the weld joint will be located, so location of the weld joint, design of the weld joint and what sequence of welding or assembly will be adopted. So, that such kind of the residual stress development is minimized further when the weld joint is subjected to when the weld metal

is deposited if it is having convex contour because of the contraction it sets in the compressive stresses at the surface.

As compare to the case when the weld joint having the concave bead geometry and contraction in this case sets the tensile residual stresses. So, the bead geometry basically a concave bead geometry is to be avoided in order to reduce the possibility of the setting of the residual stresses. And also reducing the possibility of the stress concentration because of this concave bead geometry.

There is one more there are two more technique which can be adopted in order to control the cracking of the Q and T steels apart from the weld joint design locating it properly sequence of the welding in assembly having the concave bead convex bead geometry avoiding the concave geometry.

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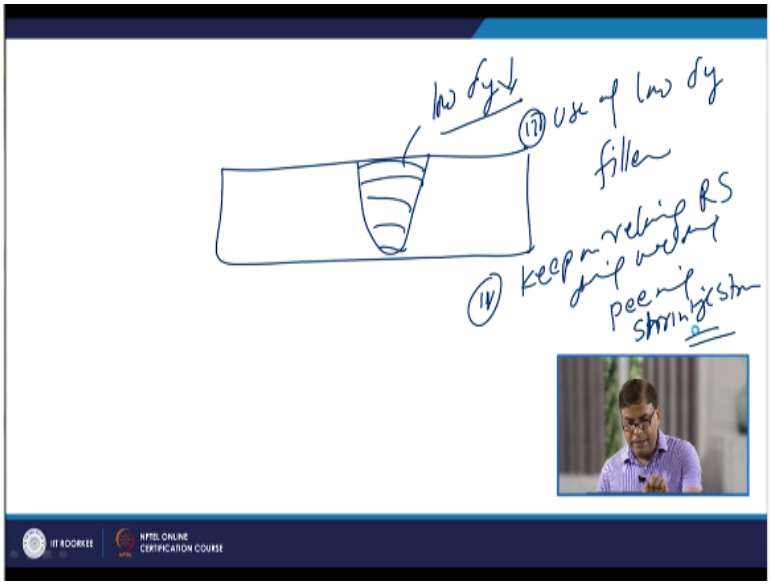

We can also lower the development of the residual stresses by selecting the filler or the weld metal of the lower yield strength. So, that since the maximum residual stress which can be developed in weld joint is up to the yield strength of the weld metal. So, if we use the low yield strength weld metal low yield strength filler then the maximum magnitude of the residual stresses which will be developed those will also be reduced.

So, use of the low yield strength filler is the third option and the fourth one is to keep on reliving residual stresses during the welding. So, after each pass we perform peening or peening using the hammer on the already deposited weld bead. So, that the shrinkage stresses are relived, so these are the 4 aspects or 4 steps which can be taken in order to control the possibility of the cracking of the Q and T steel weld joints.

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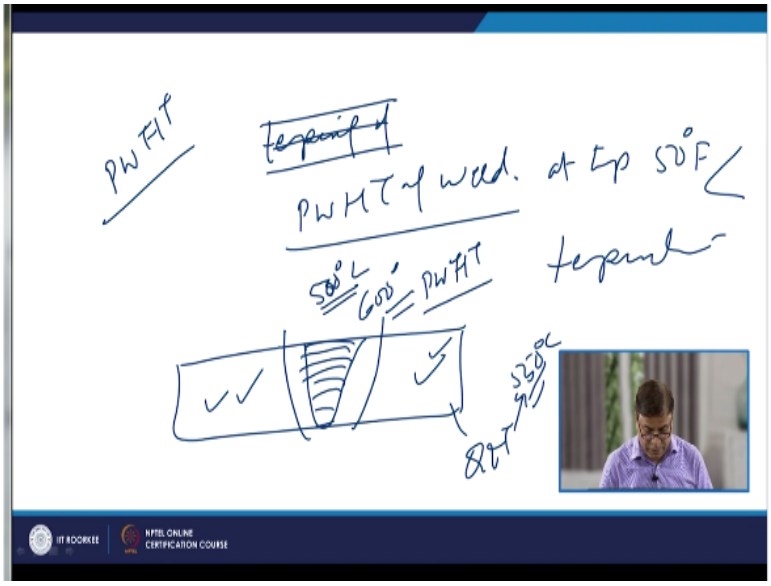

In any case if the PWHT is to be carried out of the entire assembly in order to restore the complete set of the properties. In that case the tempering of the or you can say not tempering but PWHT heat treatment of the weld joint is carried out at temperature about 50 degree Fahrenheit less than the tempering temperature, why. Because like say this is the weld joint this is the plate and this is the weld joint which has been made.

And this is the steel which has been quenched and tempered say tempering has been carried out 550 degree centigrade. So, the base metal will have the properties corresponding to the quenched and tempered conditions at 550 degree centigrade. And if we have these plates have been subjected to the welding and in order to regain most of the properties lost due to the over tempering or unfavorable welding conditions.

Then the PWHT which is to be used for improving the properties of the such weld joints. The maximum post weld heat treatment temperature under such conditions should be used like 500

degree centigrade, 50 degree centigrade less than the tempering temperature of the base metal. So, that the base metal properties are not compromised because post weld heat treatment if carried out at 600 degree centigrade.

Then the base metal properties will be over temper and they will be soft and yield strength will be reduced. So, in order to avoid the possibility of over tempering of the Q and T steel during the post weld heat treatment. The post weld heat treatment temperature should be 50 degree Fahrenheit lower than that of Q and T quenched and tempered steels tempering temperature.

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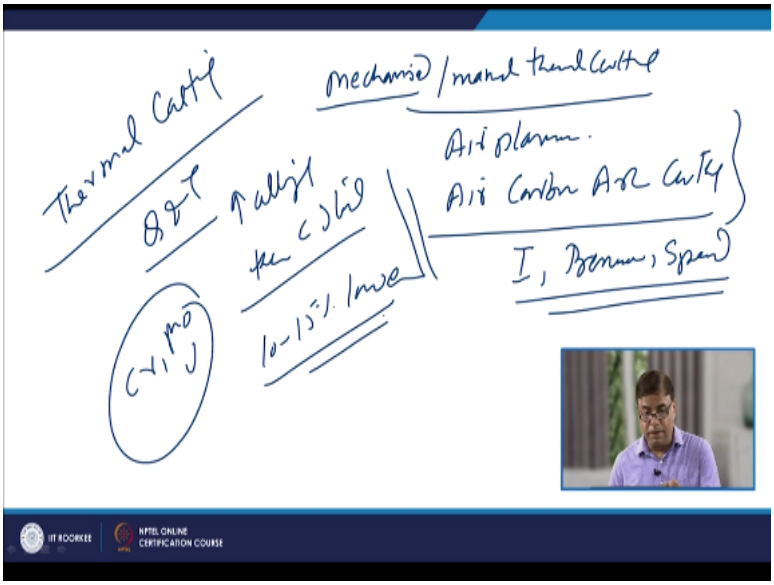

Now we will talk about the another aspect related with the thermal processing of the Q and T steel is thermal cutting. Like frequently it is required to cut the required size of the blank from the large size plate, so that these can be further processed in order to get the desired size and shape of the component. So, we can use the mechanized or manual thermal cutting.

Thermal cutting we may perform using the air plasma or we may perform air carbon arc cutting process. So, in these cases basically the current being used for generation of heat and the pressurized air which is being use to blow away the things and the kind of the cutting speed which is being used, these are the 3 important parameters which are used. So, since the Q and T steels have the alloying concentration then the carbon steels.

And that is why the cutting speed being applied for thermal cutting of the Q and T steels that will be about 10 to 15 % lower. Then that is used for the thermal cutting of the plain carbon steel and sometimes the presence of chromium, molybdenum, vanadium in these steels interferes with the cutting. So, that must be cleared or to facilitate the cutting using in presence of these elements we need to cut down the speed or reduce the speed especially the cutting is happening or the cutting is (()) (26:42).

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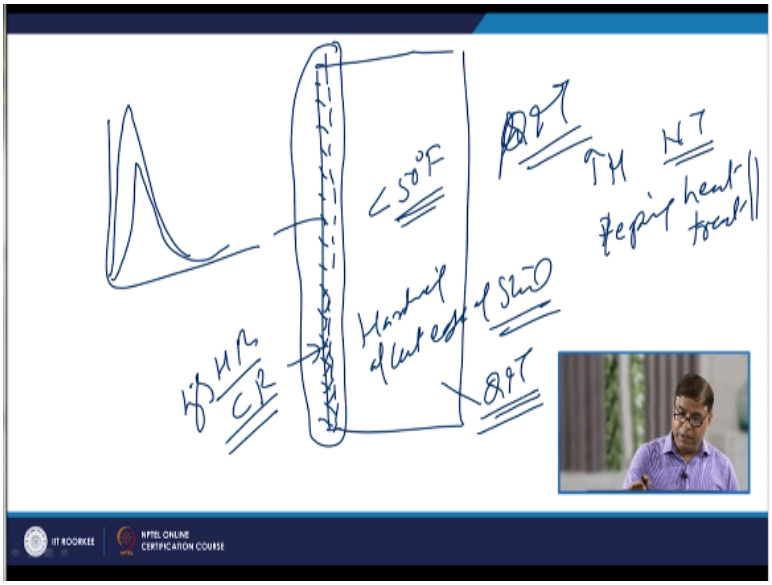

So, whatever the method of the cutting is being used, it the thermal cutting using the air carbon arc cutting method or air plasma cutting method. Basically the kind of the thermal cycle experienced by the cut edge will be similar to that of the welding except that here only one side of the edge is being affected due to the thermal cycle. So, thermal cycle for which the base metal being exposed is similar to that of the welding.

And that is why the cut edge will be experiencing the weld thermal cycle like this and the distance slightly away from the weld thermal cycles will be experiencing further lower heating rate lower cooling rates, lower peak temperatures. So, the zone which is very next to the cut edge experiences very high heating rate and likewise high cooling rate.

So, this cooling rate conditions are high enough for the hardening of the cut edge of steel. So, we need to see normally Q and T steels when subjected to even higher cooling rates. They offer the

quite good combination of the microstructure, so the despite of increase in hardness the toughness or notch toughness is not very badly compromised. But still whatever is there if that is not sufficient for a given purpose then we need to apply the tempering post cutting tempering heat treatment**.**

And in this case the tempering treatment will be applied to the zone which has been affected because of the heat which was applied during the cutting. So, the tempering of this zone is carried out and if the entire plate is to be subjected to the heat treatment after the cutting. Then we use the 50 degree Fahrenheit temperature less than the Q and T temperature the quenched and tempered steel which has been tempered at a particular temperatures.

So, for the heat treatment after the cutting will be using the 50 degree Fahrenheit temperature less than the temperature which has been used during the tempering of that particular base metal.

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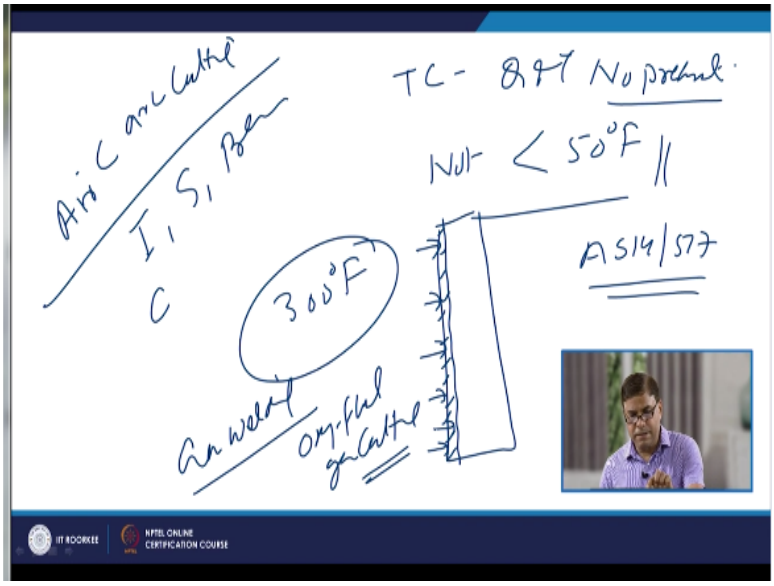

Normally, so as I said normally in case of the thermal cutting of these Q and T steels no preheat is needed, provided the plate temperature is not less than 50 degree Fahrenheit. If the plate temperature is less than 50 degree Fahrenheit then we must preheat at least this temperature. But in some cases like the steels of the high yield strength like A514 or A517 steels which are of the high yield strength, higher concentration of the alloying element.

So, the preheat of 300 degree Fahrenheit maybe given, so that it is able to offer the required set of the hardness and the toughness or notch toughness of the cut edge. And if the slack and other slack has been deposited at the cut edge then that must be cleared and removed. So, that the clean cut edge can be obtained as for as the air carbon arc cutting is concern.

During the cutting process if we have selected proper welding current proper speed and air pressure. Then the carbon enrichment of the cut edge will not be taken place but if inappropriate combination of the cutting conditions can lead to the carbon pickup by during the air carbon arc cutting process. So, this carbon which has been picked up at the cut edge will be causing the hardening or embrittlement of the cut edge.

So, this carbon rich layer from the cut edge is to be removed, so that unnecessary hardened layer from the cut edge can be taken care of as for as the gas welding is concern. Normally the oxy fuel gas cutting method is not applied for Q and T steels because the gas cutting process supplies lot of heat input.

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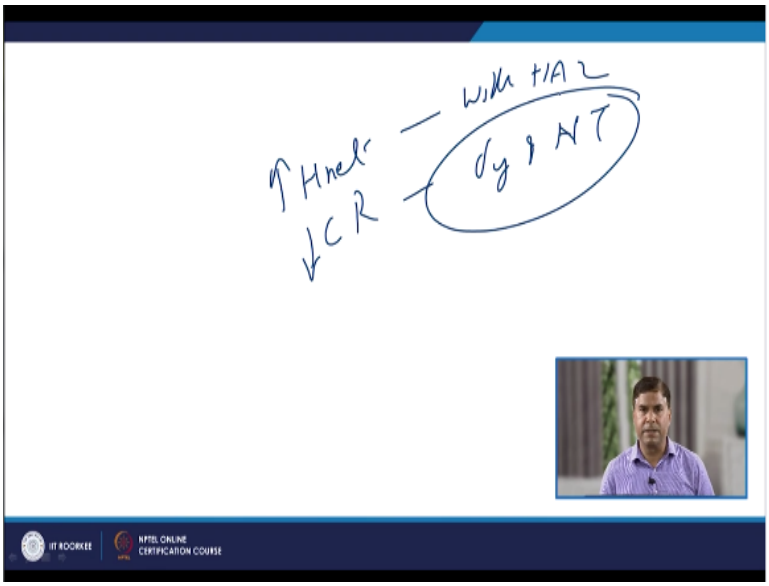

Heat input for the cutting purpose is very high and that is why it results in very wide heat affected zone as well as due to the high heat input the cooling rate experienced by the cut is also very low. So, this deteriorates the yield strength and notch toughness of the cut edge of the steel and that compromises with the mechanical properties of the cut edge of the steels significantly.

So, that is why the gas welding process is normally not used for cutting of the Q and T steel. Now I will summarize this presentation, in this presentation basically I have talked about the different aspects related with the post weld heat treatment of the Q and T steel weld joints and he kind of welding technique which is to be used for depositing the metal during the welding.

And what are the various implications related with the thermal cutting of the Q and T steels, thank you for your attention.