Weldability of Metals
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Lecture-30
Weldability of Cr-Mo Steels-III

Hello, I welcome you all in this presentation related to the subject weldability of metals and we are talking about the weldability of the chromium molybdenum steels. In the previous presentation we have talked about the welding metrology and the kind of preheat temperatures to be used for successful welding of the steels from molybdenum steels. So, that related problems of the embrittlement of the weld and heat affected zone or the hydrogen induced cracking related tendencies can be avoided.

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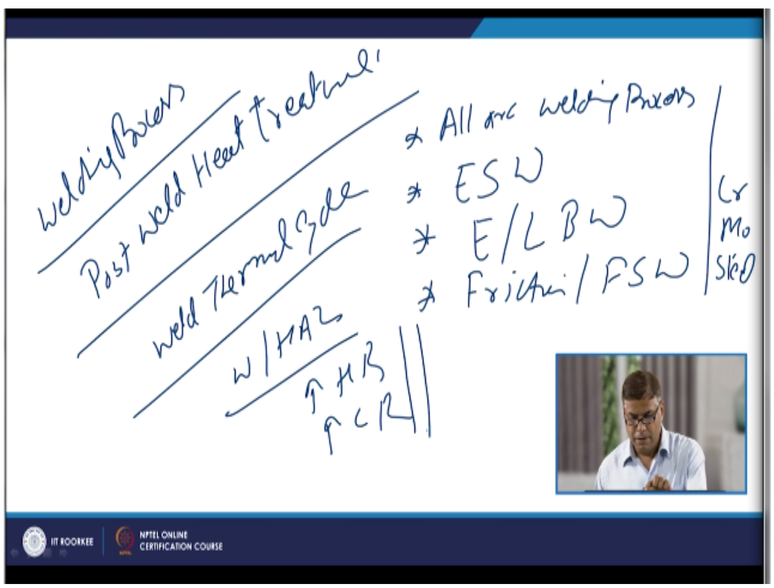

In this presentation basically will be talking about the welding processes which are used and the welding conditions for joining the chromium molybdenum steels. Thereafter we will see the kind of the post weld heat treatments post weld heat treatments which are needed for the chromium molybdenum steels. So, we know that the express the welding process is concern all are welding processes like shielded metal arc welding process.

Some as arc welding process, gas metal and gas tungsten arc welding process, plasma arc welding process all those can be used apart from that high heat in process like electro slag welding. And high energy density processes like electron beam and the laser beam welding processes and the solid state welding process like the friction welding or the friction stir welding processes also can be used for joining of the chromium molybdenum steels.

So, but they are like very peculiar situations because the kind of the weld thermal cycle which is generated during the arc welding processes the weld as well as the heat affected zone. Both experiencing the high heating rate as well as high cooling rate and these are fond to be troublesome as for as the welding of the chromium molybdenum steel is concern.

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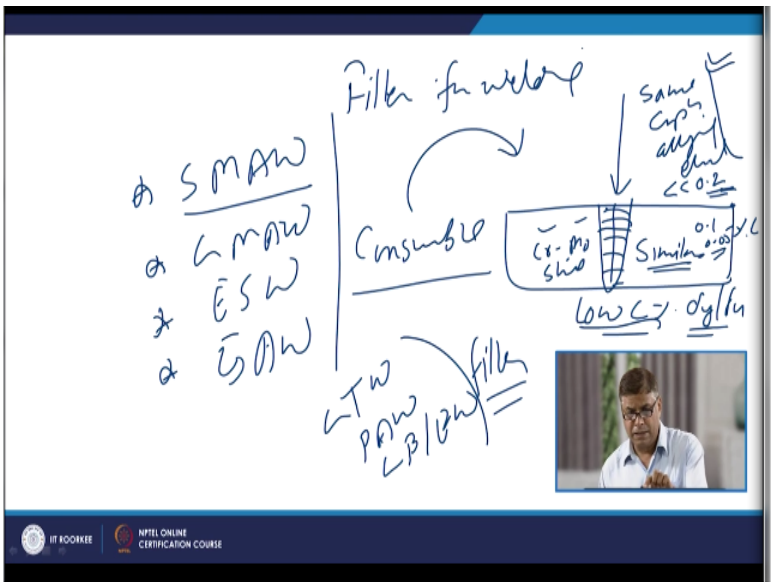

Therefore to deal with these situations especially when we are welding with the thick sections we need to use the suitable filler for welding process. So, if we talk of like say the shielded metal arc welding process or the gas metal arc welding process electro slot welding process or like say the submerged arc welding process. In all these processes the welding consumables are used, so like say the 1 typical chromium molybdenum steel plate is to be welded.

Then how the consumables will be chosen for welding the chromium molybdenum steel plates using these consumable arc welding process or in the case of like the GTAW or the PAW processes or the laser beam or electron beam process will be feeding the filler from outside. So, which type of the filler is to be used normally like there is chromium molybdenum steel plate when the same similar weld is being made.

We try use the filler of the same composition with regard to the alloying elements whatever is the chromium molybdenum is present in the base metal. Similar concentration of these elements are incorporated or the filler metal having the similar percentage of the chromium and molybdenum in the filler metal are used. But efforts are always made that the carbon content in the filler is less than what was there with the base metal.

So, if the base metal is having 0.2% then we will try to use 0.1 or like say 0.05 whatever % , so the filler will be used the such kind of the fillers will be used which will be having the lesser carbon content. But almost similar type of the alloying elements in form of chromium and carbon but whenever this situation is applied for welding we get the weld metal of the low carbon percentage.

So, our yield strength and ultimate strength of the joint as well as the weld joint is concern that will be lower but this will be showing the lesser tendency for the embrittlement. So, there are different situations if we need 100% joint efficiency then the filler will have the all alloying elements similar to that of the base metal. But if we can survive if weld joint of the chromium molybdenum can serve the purpose even with the lower strength. Then we will try to prefer to use the, we will prefer to use the filler having the lower carbon content while other alloying elements are similar to that of the base metal.

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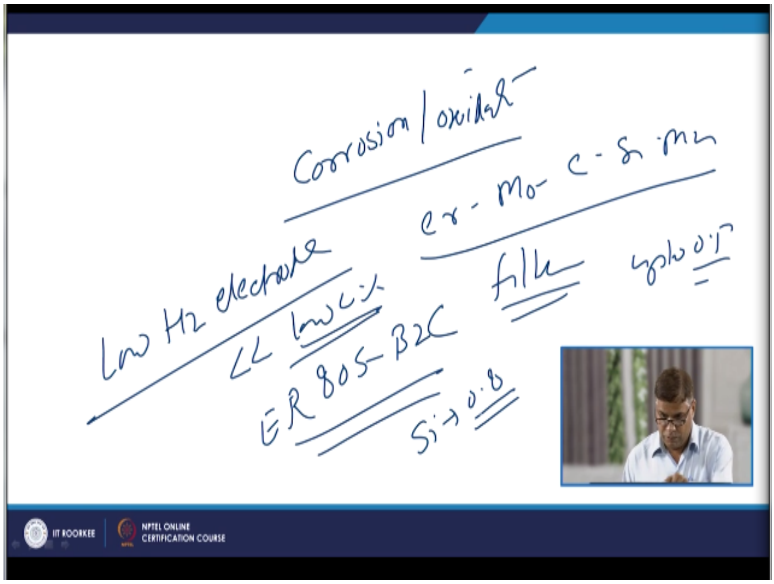

Say for example if the weld joint will be required to have the good corrosion resistance and good oxidation resistance. Then we will try to see whatever is the composition of the base metal in terms of the chromium, molybdenum, carbon, silicon, manganese all those alloying elements are also present in the filler. So, that our corrosion resistance of the weld metal region is similar to that of the base metal.

And another important thing is like low hydrogen electrodes, in case of the SMW process like low hydrogen electrodes are used having very low carbon percentage. So one typical filler is there like ER 80S-B2C this is 1 typical filler having the lower carbon content and the low hydrogen electrode. These fillers will also be having the alloying elements similar to that of the base metal except the carbon but the silicon is also high.

In normal base metal like silicon is up to 0.5 but in these in the fillers it is preferred to have the silicon up to 0.8. So, that some of the flex related reactions can be facilitated and the silicon can really perform the effective role in development of the sound weld joint.

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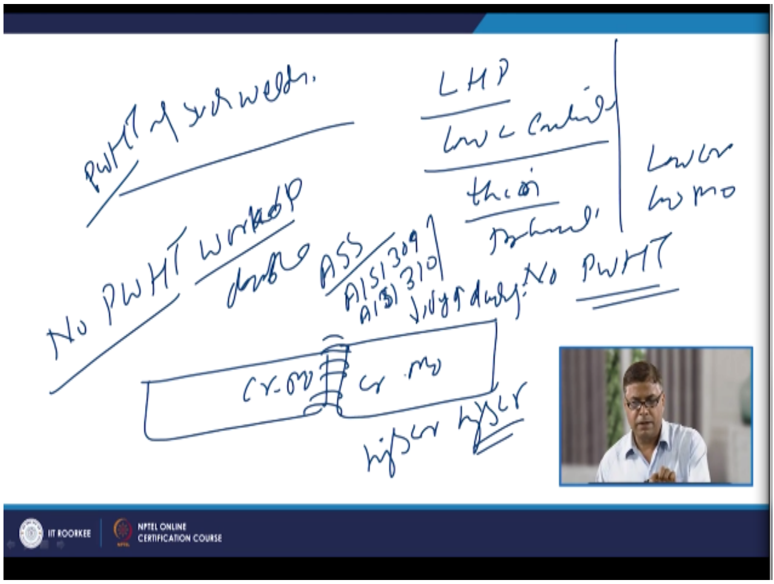

As per as the PWHT of such weld joint is concern like when we are using the low hydrogen practices very low carbon content. And thin section is to be welded using suitable pre heat probably we do not need with the low chromium, low molybdenum steels, no post weld heat treatment is needed. Another possibility is that when no PWHT is workable or it cannot be implemented not workable or not doable.

Then the chromium, molybdenum, steel weld joints are joined using the fusing welding process with the help of austenitic stainless steel fillers and typical fillers are like AISI307 and AISI310. So, both these steels are of the high chromium, high nickel when these are welded but these are austenitic, so because of these are austenitic of the lower yield strength and the higher ductility.

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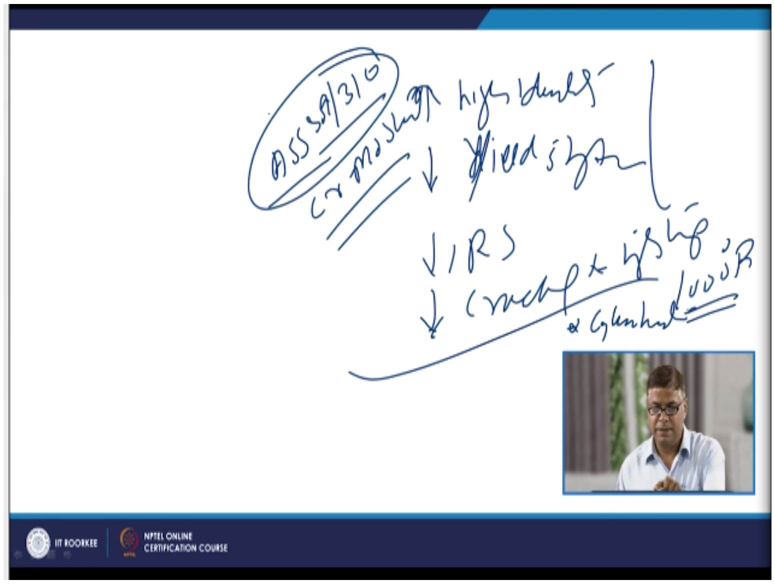

So, from the cracking point of view use of the austenitic stainless steel fillers is favorable because it results in the high ductility in terms of percentage elongation. But the lower yield strength and because of the high ductility and lower yield strength residual stress related problems are reduced cracking tendency is reduced due to the embrittlement. But there is another form of problem which is imposed.

When the chromium like austenitic stainless steel fillers like AISI309 or 310 or used for welding of the chromium molybdenum steels. So, the kind of problem which is experienced is of the different kind especially if these weld joints are to be used at a high temperature say 1000 degree Fahrenheit and that temperature we come across the another kind of problem. And there is another one where cyclic heating is involved of the chromium molybdenum steel weld joints which are welded using the austenitic stainless steels fillers.

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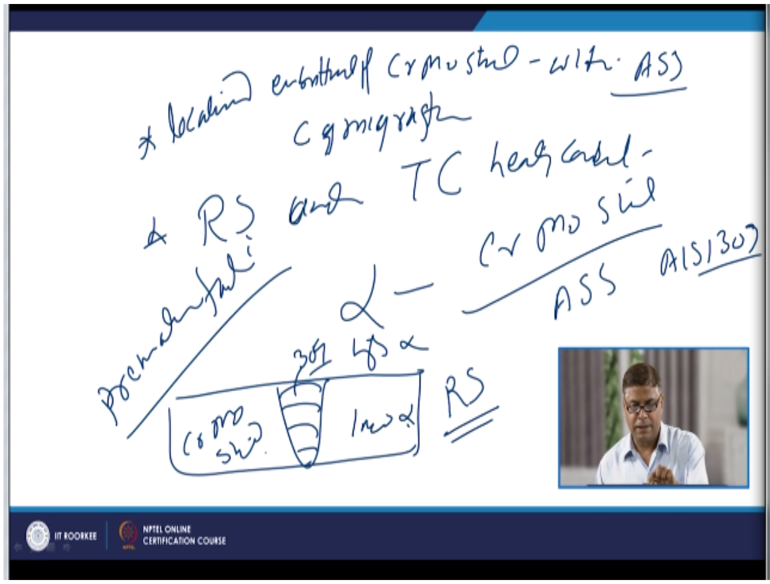

So, they are 2 issues, 1 is associated with the localized embrittlement of the chromium molybdenum steel welds made with the austenitic stainless steel fillers. This happens primarily due to the carbon migration and the second problem is associated with the development of the like residual stresses under the thermal cyclic heating conditions. Since the thermal expression coefficient of the chromium molybdenum steel is significantly different from the austenitic stainless steels like AISI309 or 310.

So, because of the higher difference when these are used as a filler, so basically weld is dominated by 309 having the higher alpha and the lower alpha value is there for the base metal in form of chromium molybdenum steels. So, whenever cyclic heating and cooling is carried out this develops the residual stresses due to the cyclic heating and cooling and that promotes the premature failure. So, premature failure is tendency is promoted when the austenitic stainless steel filler is used in welding of the chromium molybdenum steels.

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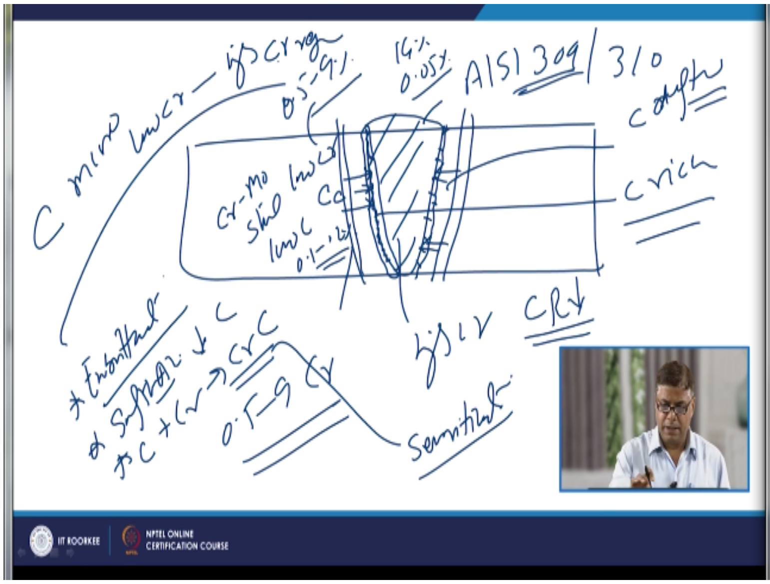

On the other hand the carbon migration is the another problem which is encountered during the welding of the chromium molybdenum steel when such kind of the weld joints are used at a high temperature. Say this is the weld metal of the high chromium content AISI either 309 or 310 steel and both sides we have chromium molybdenum steels. So, which are of the low carbon as well as low chromium at the low carbon but not as low as that of the **A** 310 carbon here is like say maybe 0.1 to 0.2%.

On the other hand chromium is like say it can be 0.5 to 9% on the other hand the carbon content in the weld metal maybe like say 0.05 and the chromium content is 16%. So, the weld is having the higher chromium while the base metal is having lower chromium say 0.5 to 9%. So, in this situation when the welding is carried out the carbon from the base metal which is having like 0.1 t0 0.2 it is starts to get diffuse towards the high chromium region.

So, the carbon is starts diffusing from the high carbon steel from the low carbon steel side to the high chromium molybdenum side. So, diffusion of carbon towards the high chromium weld metal zone is starts and in that case it is starts to segregate somewhere at the fusion boundary. Because the austenitic stainless steel has the under the austenitic stainless steel has high affinity as well as solubility to the carbon.

So, as a result of this carbon may start diffusing and but it mostly segregates at the fusion boundary. So, a carbon rich zone is formed near the fusion boundary at the same time region where from the carbon has diffused towards the fusion boundary that zone becomes depleted of carbon. So, there is 1 region where depletion of the carbon has taken place and there is 1 region near the fusion boundary where the enrichment of the carbon has taken place.

So, they are 2 effects 1 is the embrittlement due to the high carbon content near the fusion boundary. Second is the softening of the Hz due to the depletion of the carbon, due to the carbon content reduction. And there is third problem this carbon reacts with the chromium to form chromium carbide and once the chromium carbide is formed it promotes the sensitization which means the corrosion resistance of such kind of the locations will be reduced drastically as compared to the other locations where the chromium content is high.

So, this entire problem is attributed to the carbon migration from low chromium region to the high chromium zone region. And then this carbon starts segregating there, so this will be weakening the heat affected zone due to the deficiency of the carbon in very localized way and embrittlement next to the fusion boundary of the steels.

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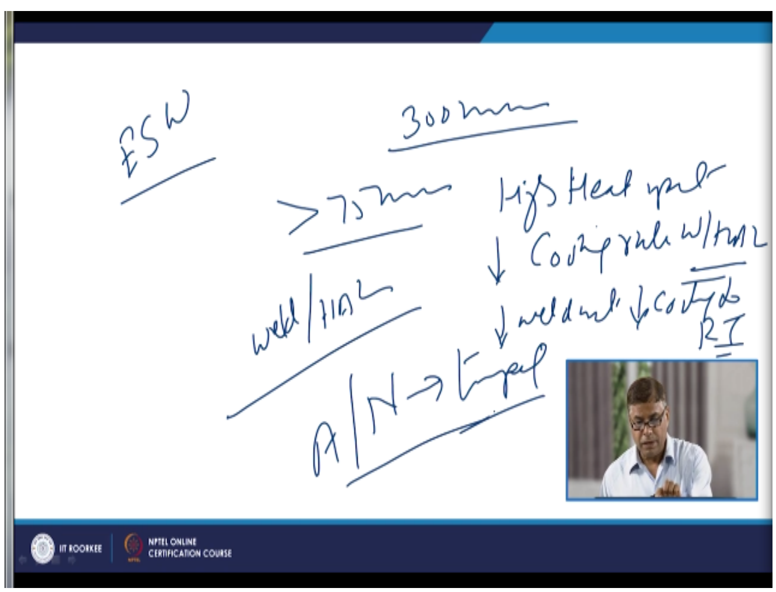

Apart from the issues related with the use of filler in fusion welding of the chromium molybdenum steel we can also use the electro slack welding. We know that the electro slack welding can be used for welding the thick plates up to 300mm. So, whenever the plate thickness to be welded of the chromium molybdenum steel is greater than 75 mm electro slack welding is used.

But electro slack welding is basically very high heat input process because of that high heat input the cooling experienced by the weld metal as well as the heat affected zone are very low. And therefore after completion of the weld we can allow the weld meant to cool down cooling to the room temperature without problem of the without possibility of the cracking or embrittlement tendency.

But due to the high heat input since the weld and the Hz structure is completely modified and therefore we need annealing normalizing followed by the tampering of the entanglement, so that the properties can be restore.

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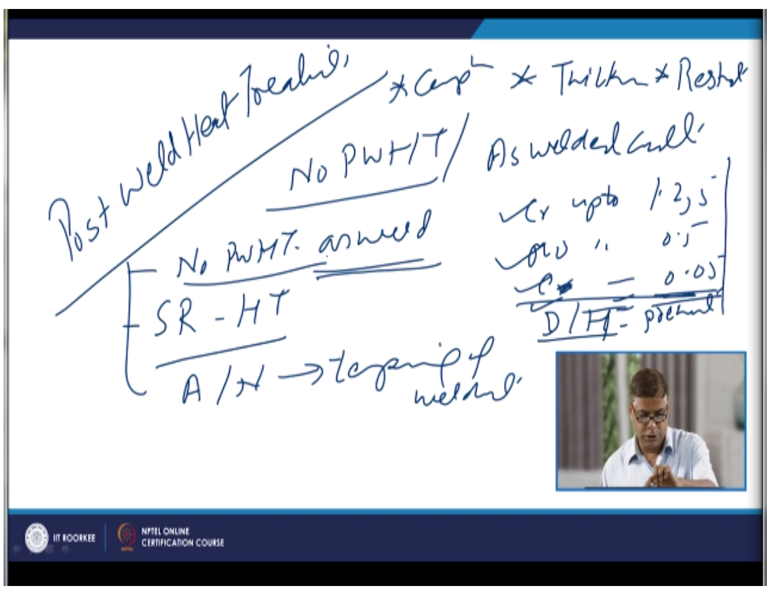

Now will be talking about the kind of the post weld heat treatments which are used in case of the chromium molybdenum steel weld joints. So there are the kind of the heat treatment to be used will primarily with the function of the composition like low chromium, low molybdenum, low carbon very less thickness. And very limited restraint during the welding probably we do not need PWHT, no PWHT and weld joints are used in as welded conditions.

So, very less thickness, very low chromium and carbon content, no PWHT is required so, so they are 3 types of the heat treatment conditions which are applied one is no PWHT that is the as welded joints. Second is the stress relieving heat treatment, and the third one is that complete restoration of the properties through the annealing, normalizing followed by tampering of the weldment.

So, these are the 3 types of the heat treatment, so when the chromium content is up to chromium up to 1.25, molybdenum up to 0.5 and carbon is very less like 0.5 very low carbon content or the normal carbon range. But the filler is of the very this is the carbon, so the low very low carbon is used as a filler in that case whatever the ductility the toughness offered by the weld that is sufficient for the applications.

So, **so** use of the suitable preheat with the low chromium, low carbon, low molybdenum the kind of ductility and the toughness realized is sufficient for the most of the applications. So, no post weld heat treatment is needed for such kind of the situations.

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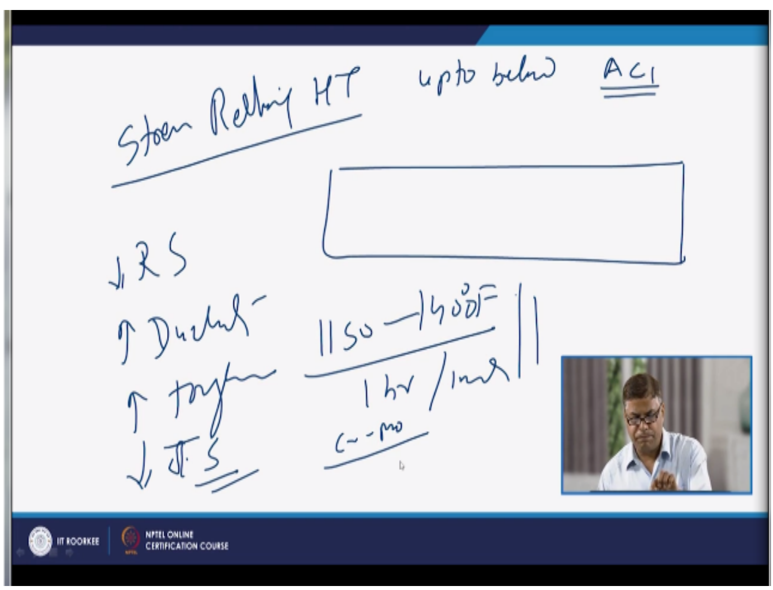

Another is the stress relieving heat treatment obviously we will be requiring the heating maximum up to or below the lower critical temperature level. So, whenever heating is done for the stress reliving purpose it will be reliving the residual stress, increasing the ductility of the weld joint, increasing the toughness of the weld joint.

But certainly the yield strength or the tensile strength of the joint will be significantly reduced. So, the normal tampering conditions like 1150 to 1400 degree Fahrenheit for 1 hour per instruction is the kind of the stress reliving temperatures are used for the stress reliving conditions will always see that for the different chromium molybdenum composition. There is always range of temperature 1400 degree Fahrenheit whatever is the range of temperature.

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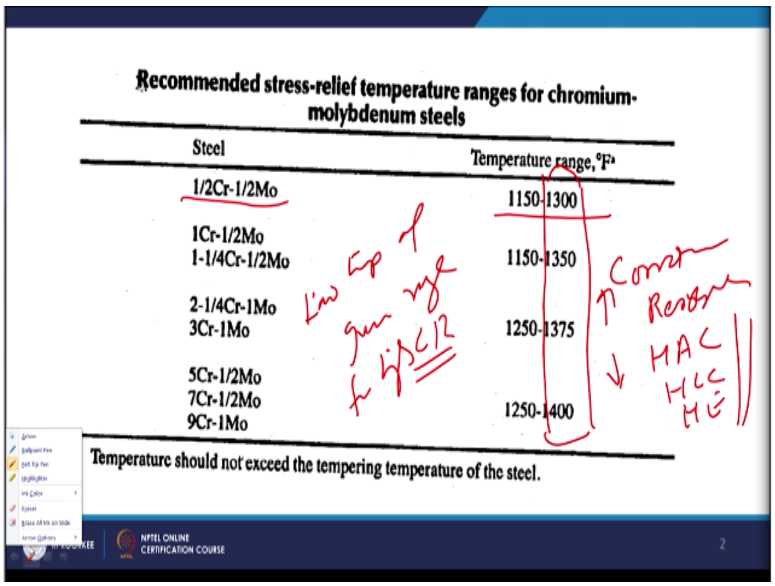

In that range like say for 0.5% chromium, 0.5% molybdenum normal stress reliving temperature range like say 1150 to 1300 degree centigrade. So, among these lower temperature ranges are normally used like low temperature of the given range is used for the conditions when high grip resistance is important.

On the other hand the higher temperature of the given range for a stress reliving is used when we want the very good corrosion resistance or we want to reduce the hydrogen assisted cracking tendency or hydrogen induced cracking tendency or hydrogen embrittlement. So, if these tendencies are to be reduced then the stress reliving treatment will be carried out at using the higher temperature value in a given range for a particular steel.

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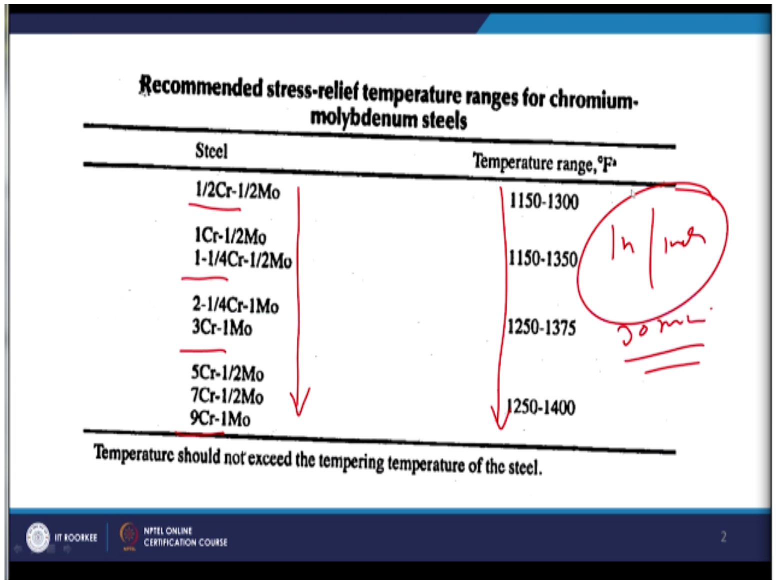

Another aspect which we can see here is this that as the concentration of the alloying element is increasing. The kind of the stress reliving temperature is also increased and this exposure is given as I have said 1 hour for per inch and minimum 30 minute exposure is given in an any case. So, 1 hour per inch section thickness is the kind of the time which is used for the purpose of the for the purpose of reliving the residual stresses.

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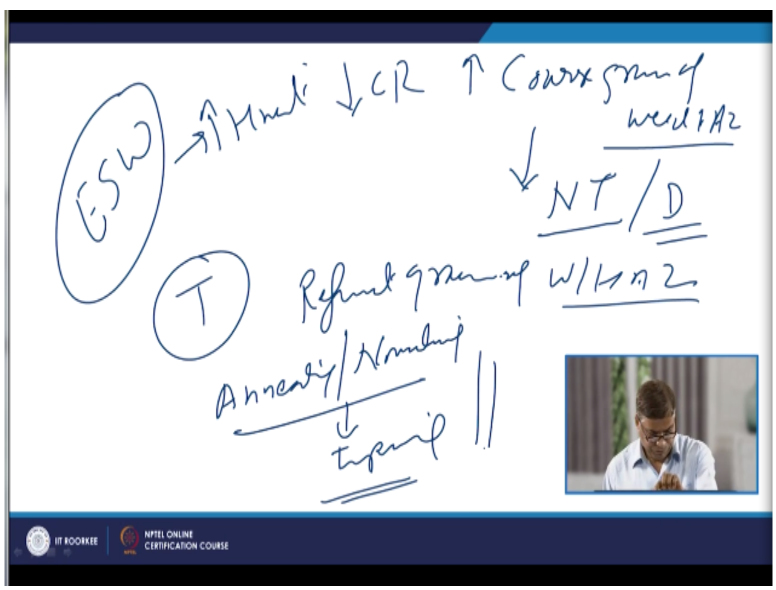

So, but all the weld joints which are produced using the electro slack welding of using the very high heat input, low cooling rate leading to the very coarse grain structure of the weld as well as the heat affected zone. So, this will be compromising the notch toughness and the ductility of the weld joints significantly. So, in order to improve the toughness of such kind of the weld joints basically the refinement of the grain structure of the weld and Hz is achieved.

And for this purpose normally a sequence of annealing or normalizing heat treatment followed by the tampering is performed on the electro slack welded chromium molybdenum steel weld joints. So, that the grain structure can be refined and the properties can be improved now in which stage the heat treatment is to be performed.

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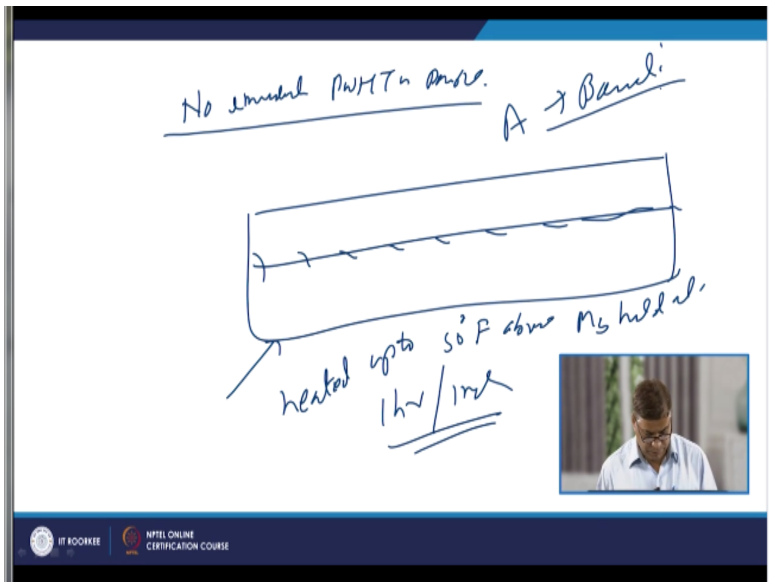

Like say if no immediate PWHT is possible in that case the after completion of the weld joint like say the weld joint has been completed then it is heated. As soon as the weld joint is completed it is heated up to 50 degree Fahrenheit above the Ms temperature and it is held at that temperature for 1 hour per inch thickness of the section being welded. So, this will help to transform the austenite into the bainide.

And thereafter we can give the required heat treatment and in case when the post weld heat treatment is possible immediately, immediately means then the weldment will be allow to cool down to the room temperature. And thereafter the stress reliving heat treatment or the required annealing or normalizing followed by the tempering heat treatment will be carried out.

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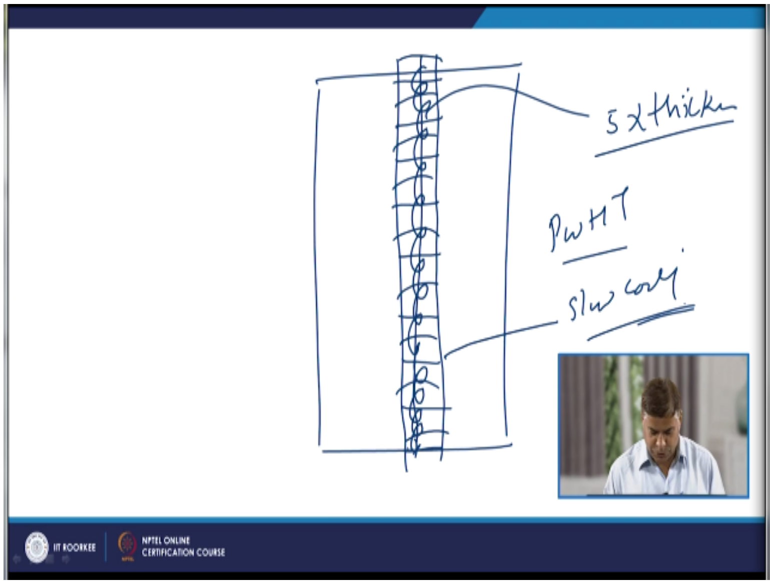

If the entire weldment cannot be exposed to the high temperature using the suitable furness localized heating can be applied. So, localized heating can be done like say this is the weld joint line and post weld heat treatment is to be carried out up to the required temperature. Then we may use flame or we may use induction heaters up so that sufficient width is heated using the suitable heat source.

And this width at which is to be heated to the high temperature will be about 5 times of the thickness of the plate which has been joined. So, post weld heat treatment will be involving the heating wider zone and once it is given the exposure to the high temperature for sufficiently long time thereafter slow cooling is giving. So, that it can relive the residual stresses as well as incorporate the properties which will help in improving the toughness, inducing the ductility.

And having the required combination of the properties for successful performance of the weld joint. Now I will summarize this presentation, in this presentation basically I have talked about the different welding processes and the way by which these affect the properties of the chromium molybdenum steel weld joints. And how does the post weld heat treatment affect the characteristics of the chromium molybdenum steel weld joints, thank you for your attention.