Weldability of Metals
Prof. D K. Dwivedi
Department of Mechanical and Industrial Engineering
Indian Institute of Technology-Roorkee

Lecture-16
Weldability of Medium Carbon Steel and High Carbon Steel

Hello I welcome you all in this presentation related with the subject weldability of metals and we are talked about the weldability of low carbon steel. And also some of the aspects related with the weldability of the mild steel, some of the points associated with the weldability of the mild steel I will be taking a first. Thereafter we will go for the weldability of medium carbon steel and high carbon steel.

So, as for as the weldability of the mild steel is concerned we have seen that normally the weldability is good. But if the restraint conditions are high the carbon content is 0.3, manganese content is 1.4 and the thickness is more than 25 mm. Then we need lot of precautions related with the low hydrogen welding procedure preheat as well as post heat treatment. And also like if the high heat input is used then it leads to the reduced toughness of the weld metal. And the reduced toughness of the heat affected zone also due to the coarse grain structure.

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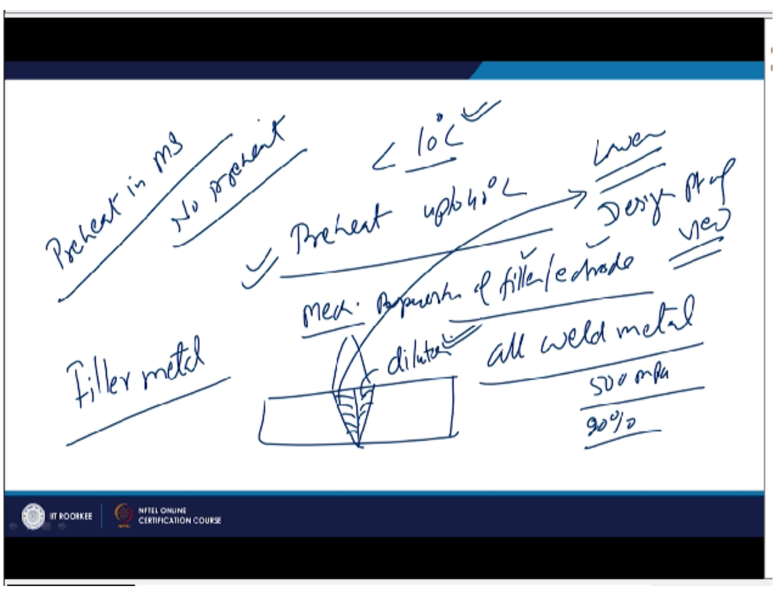

So, as for as the preheat is concerned in case of the preheating in mild steel is concerned. Normally no preheat is used under the ambient condition, ambient means the temperature condition is more than 10 degree centigrade then normally no preheat is needed for thickness is up to the 25 mm. But if the temperature condition is less than 10 centigrade then preheating is done up to 40 degree centigrade.

So, under the normal ambient condition temperature is low lower than the 10 degree centigrade then only preheat is needed. Otherwise preheating is normally not needed in case of the mild steels. Then another aspect is the choice of the filler metal for mild steel, so like when we go in the market and try to look for the kind of mechanical properties being offered by the various electrodes and the fillers.

Then they mention the mechanical properties of that particular filler or electrode when it is tested for all weld metal. So like say all weld properties for a given filler or the electrodes is of the 500 MPA yield strength. Ductility is 20% but when the same filler is used for welding of the mild steel then obviously some of the base metal will be mixing up with the filler metal and changing the composition.

This is called dilution, so intermixing of the fuse based metal with the electrode metal will be leading to the change in composition. So, the weld metal properties do not necessarily correspond to the properties of the filler metal or the electrode exactly. But they are normally found lower than the filler metal or electrode properties.

So this point is to be kept from the design point of view that the weld properties may be poorer than the filler metal or electrode properties written in the package of that filler or the electrodes. So, this is the primarily attributed to the dilution change in the composition of the filler metal due to the dilution.

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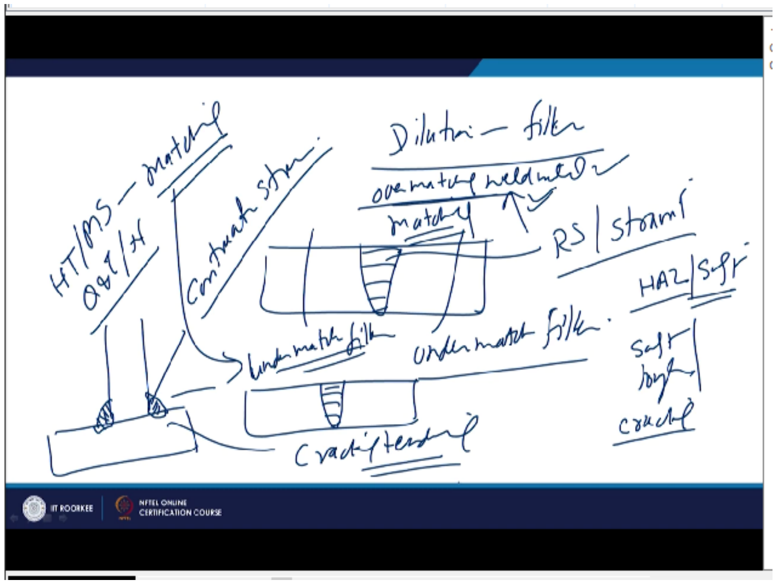

So, now here it comes to the like how to choose the filler metal normally we by considering the dilution of filler is selected for the various conditions. Whether the weld metal will offer the properties same as that of the base metal, that is called matching properties. The matching properties and when or matching weld metal, when the weld properties are better than or the yield strength is higher than the base metal.

Then it is called over matching weld metal, in that case the weld metal will be stronger than the base metal and the heat affected zone. So we need to keep in mind and sometimes under matching filler is also filler or electrode is also used intentionally as per the case. So if in most of the cases like the mild steel is being welded in heat treated condition like normalized or Q and quenched and tempered condition.

So, heat treated mild steel normally the welded using the matching filler, so that the weld metal properties or similar to that of the base metal. Then there is if we choose the weld metal the filler metal which will be offering the properties of which will be greater than the base properties means for over matching fillers. There will be higher the contraction strains which will be generated in the weld metal.

And the, so the residual stress and the strains which will be locked in the weld metal near the heat affected zone. So, because of the over matching properties the heat affected zone if it is not soft, if it is not tough then it can lead to the cracking. So, when the over matching filler is used the heat affected zone must be soft. So, that it can accommodate the associated strains being generated due to the contraction of the weld metal.

So, this matching fillers are mostly used in case of the butt weld joint configuration but when we perform the fillet welding like in the t weld joint or any other situation where the fillet welding is performed in that fillet welds are developed. In that case to deal with these contraction strains, so to deal with these contraction strains we normally choose the under matching filler.

Under matching filler is means the filler is are the electrode or the weld properties will be inferior to that of the base metal means the yield strength of the electrode material or the filler material or the weld metal which will be deposited that will be lower than the base metal. And this is primarily done to avoid the cracking tendency due to the residual stress development.

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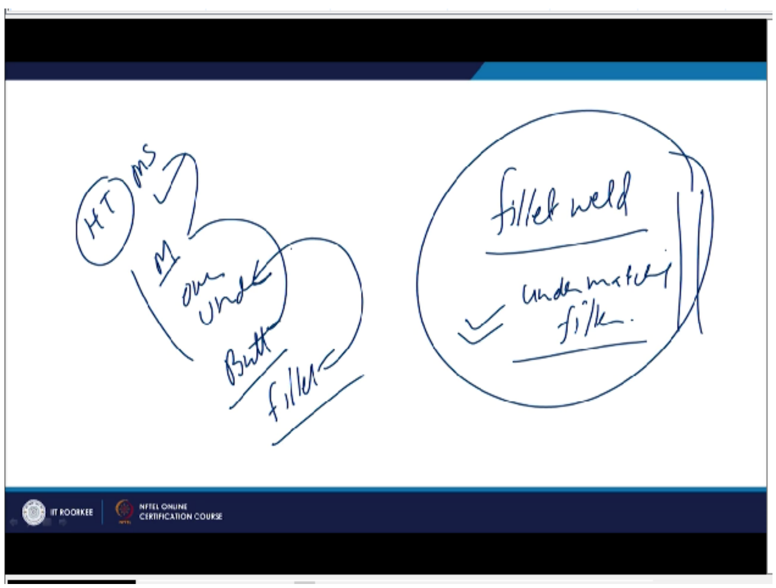

And this kind of the approach is commonly used for the fillet welds, so for fillet welds under matching filler or the electrode can be used. But this is not the very effective method for avoiding the cracking or to avoiding the stress relieving step. But certainly if the mechanical property requirement is satisfied even with the under matching filler. Then in case of the fillet welds to avoid the unnecessary contraction strains.

And the residual stresses and the cracking tendency the under matching fillers can be used, so these are the some of the aspects related to the choice of the filler metal. Whether we want the matching or over or under matching filler whether it is due performed in the butt joint configuration or the fillet weld are to be made or the which kind or the what is the heat treatment condition of the mild steel in which welding is to be performed.

So, for all matching for the heat treated mild steel or for the butt joint configuration normally the matching fillers are used, for over matching fillers the base metal and the heat affected zone must be softer. While for the fillet welds the filler or the weld metal must be inferior or softer than the base metals. So that it can reduce the tendencies for cracking or the issues related with the locked in strains in the weld metal.

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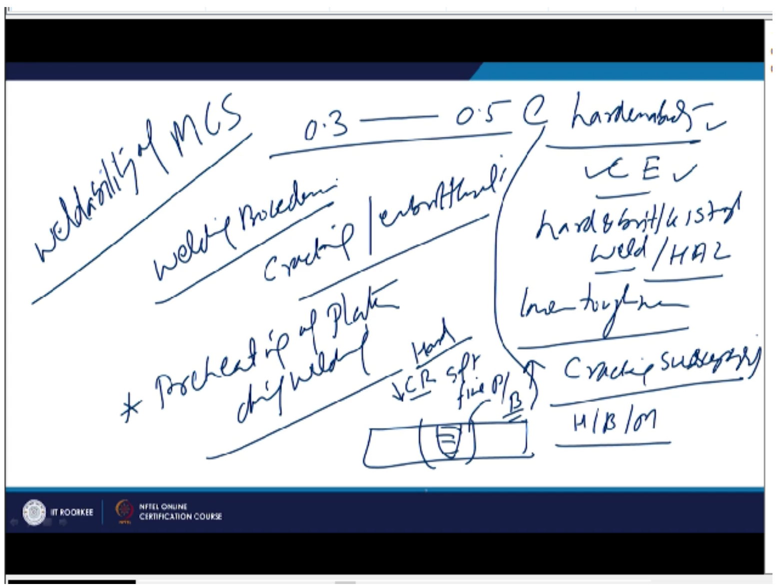

Now will be talking about the weldability of medium carbon steel, we know that the medium carbon steels have the carbon content in the range of 0.3-0.5. So, this is quite high carbon percentage as for as the hardenability is concerned because it will be leading to the quite high carbon equivalent, high carbon equivalent higher hardenability with the medium carbon steels leads to the hard, brittle, strong weld metal as well as heat affected zone which will be of the lower toughness.

So reduced toughness will be leading to the increased cracking susceptibility, so increased cracking sensitivity of the medium carbon steel is primarily due to the higher hardenability associated with the high carbon equivalent. These are the inherent properties of any medium carbon steel and therefore it is important that proper welding procedure is developed. So that the cracking tendency and embrittlement of the weld as well as the heat affected zone can be reduced.

So, what are the things which are done to overcome these issues the one the first step is the preheating of the plates or the medium carbon steels during the welding. So, though what are the factors that will be affecting, so the primary purpose is what if the preheating is not performed. The high cooling rates experienced in the weld metal as well as the heat affected zone will be leading to the formation of the hard and brittle martensite.

In both in the weld metal as well as heat affected zone which will be increasing the cracking sensitivity embrittlement of the heat affected zone as well as the weld metal. So, in order to reduce the tendency of the formation of such hard and brittle micro constituents the cooling rate is reduced. And to, so that softer phases like fine pearlite or the bainide in the weld as well as heat affected zone can be formed.

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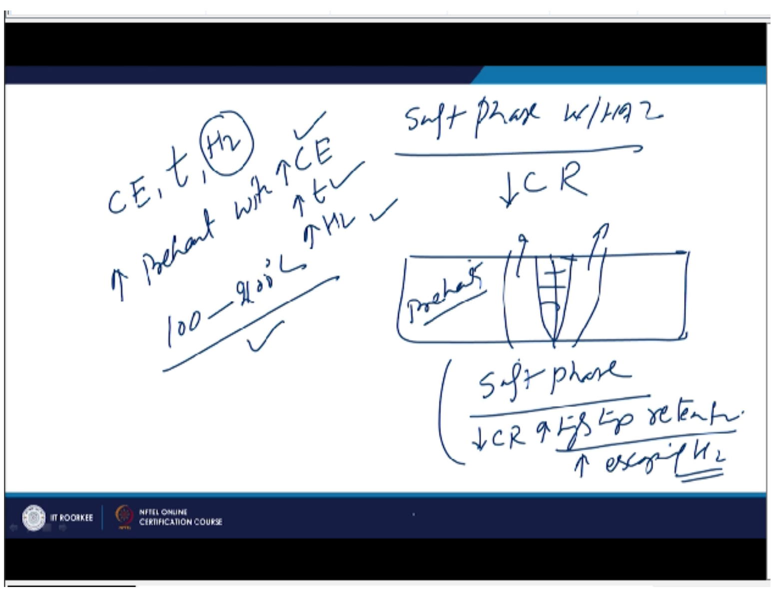

So, in order to facilitate the formation of the soft phases in the weld and in the heat affected zone primarily the cooling rate is reduced. So, to reduce the cooling rate of the weld metal as well as the heat affected zone during the welding preheating is performed. So, the extent of preheating required, so that the embrittlement of the weld as well as zone cracking sensitivity of the weld as well as heat affected can be reduced.

That will depend upon the carbon equivalent, this is one the thickness of the plate to be welded and the kind of the hydrogen which is present in the environment that will depend on the welding procedure. In general preheat temperature increases with the increase of the carbon equivalent, increase of thickness and increase in the hydrogen in the welding environment. And this temperature of the preheat normally ranges from 100-200 degree centigrade as for the CE thickness.

And the kind of the hydrogen which is to be taken care of during the welding. Once we apply the suitable preheat suitable preheat will be lower down the cooling rate will help in forming the soft phases in the weld as well as heat affected zone. At the same time reduced cooling rate will increase the high temperature retention period.

And that high temperature retention period will help in increasing the skipping of the hydrogen present in the weld as well as heat affected zone. So, the release of the hydrogen from the weld metal as well as heat affected zone will also be facilitated by the preheat and so the related cracking tendencies can be reduced.

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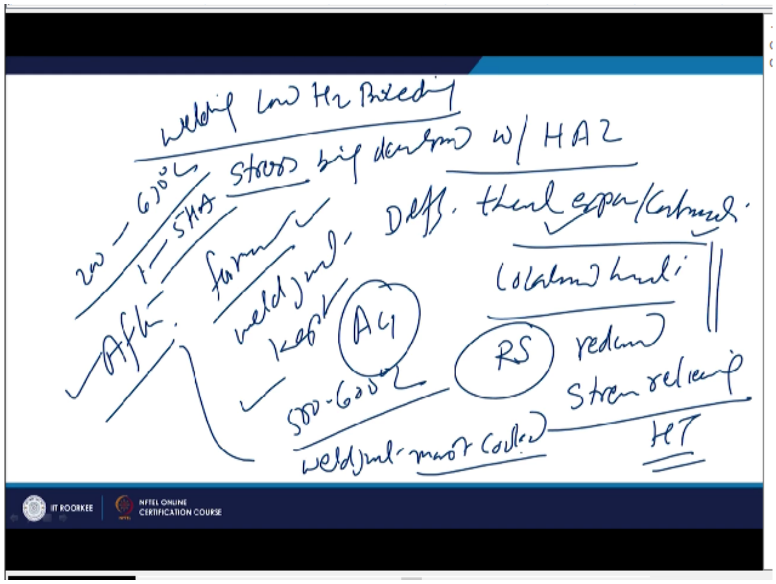

Once the weld has been developed using suitable low hydrogen welding procedure it is also required to take care of the residual stresses. A stresses being developed in the weld metal as well as heat affected zone primarily due to the differential thermal expansion and contraction caused by localized heating along the weld centre line or the weld metal. A metal near the weld centre line which is subjected to the faster heating and the cooling leads to the expansion and contraction.

But at the end of the welding some thermal strain is left locked in the weldment and that is leads to the development of the residual stress. These must be taken care of, these must be reduced or eliminated and for that purpose we need to perform the stress relieving treatment. A stress relieving heat treatment involves the heating of the entire immediately after the welding just after the welding in the furnace weld joint is kept at suitable temperature.

Normally it is below the lower critical temperature like 500-600 degree centigrade, depending upon the kind of the metal system 200-650 degree centigrade preheating depending upon the time from 1 hour to 5 hours can be performed. So, that the stress can be relieved it will depend upon the thickness the kind of the materials and the joint configurations extra. So, it will help in taking care of the reducing the residual stresses.

So, immediately after the welding the joint is kept in the furnace at the suitable temperature first sufficient time for a stress relieving. So, that the stresses locked in the weld joint can be reduced, now what we have to see that after the stress relieving has been the weld joint must be cooled slowly from the stress relieving temperature. So, cooling mass to be done slowly. So, that unnecessary due to the differential cooling of the different zones of the weld joints the distortion of the welded joints does not take place.

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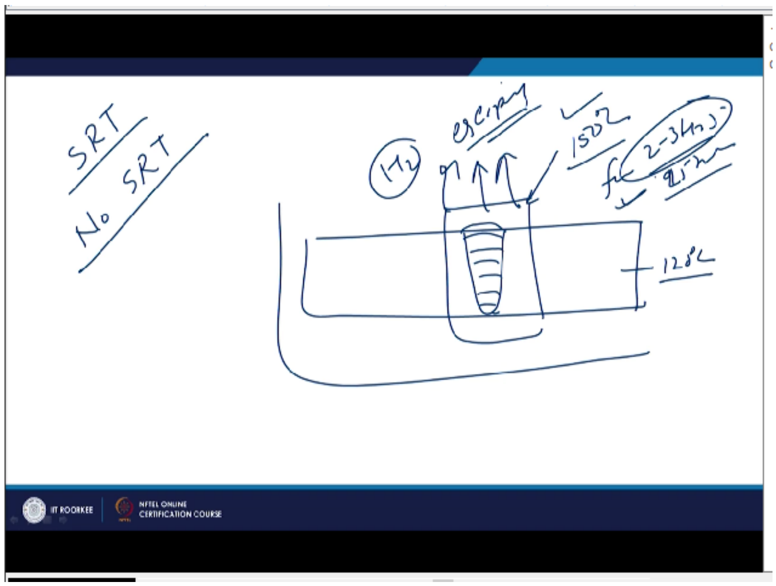

In those situations, so this a stress the relieving treatment is perform when it is possible. But when it due to the joint configuration due to the fabrication conditions if it is not possible to perform the stress relieving treatment, when no stress relieving treatment is possible then after the welding what we do we maintain the temperature say this weld joint was performed weld joint was developed using preheat of 120 degree centigrade.

Once the judgment is developed and we know that it is not possible to perform the welding. Then the entire weld joint this weld joint is given exposure of the temperature little bit higher than the preheat temperature say 150 degree centigrade for 2-3 hours. So, we do not allow the weld joints to cool down to the room temperature before the stress relieving, but immediately after the welding will put it into the furnace.

So, that the stresses can be relieved or it will be heated to little bit higher temperature like 150 degree centigrade for 2-3 hours per 25 mm section size. So, this is the kind of the duration, so that all the hydrogen which was dissolved if it is present that can escape from the weld as well as high as well as heat affected zone. So, it will help in basically skipping of the hydrogen as well as the relieving the residual stresses.

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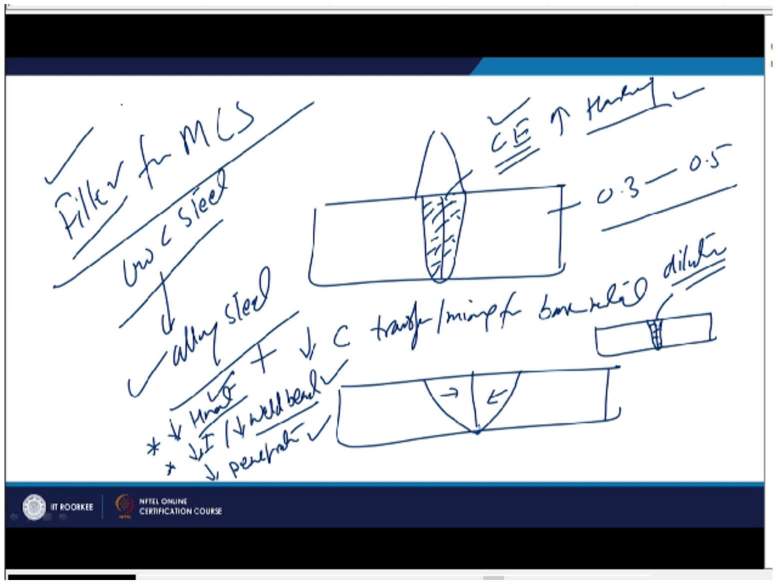

Then we will talk about the kind of the fillers to be used, fillers for medium carbon steel welding we know that the since the steel is having quite high carbon content like 0.3-0.5. So, normally we if we use the low carbon steel, then a low carbon steel filler during the welding due to the dilution carbon from the base metal will get into the weld metal. And will cause the enrichment of the weld metal with the carbon.

So this will be increasing the carbon equivalent of the weld metal, increasing the hardenability of the weld metal and causing the issues related with the embrittlement due to the hard and brittle martensite transformation. So, mostly alloy steels are selected in such a way that they do not cause much of the increase in the hardenability of the weld metal carbon equivalent is maintained at the same time.

Apart from using the low carbon steel efforts are also made to reduce the carbon transfer or mixing from the base metal. So how this can be facilitated like if the this is the base metal if we melt more amount of the base metal then more carbon will be going into the weld metal. So, what we do we try to reduce the melting of the base metal like this is the joint interface, so will reduce the melting of the base metal.

So that the limited amount of the waste metal goes into the weld metal and there by the carbon transfer the carbon from the base metal to the weld metal is reduced. This is called dilution, we try to reduce the dilution by reducing the melting of the base metal and for that purpose what we have to do we have to use we have to reduce the heat being supplied, so net heat input is reduced. So that the extent of the base metal melting can be reduced to reduce the dilutions.

So the transfer of the carbon into the weld metal is reduced, we also put, so we try to use as minimum possible welding current is as possible. So that and if the heat input if the welding current is reduced very limited amount of the heat will be generated. This in turn will reduce the weld bead size which is being deposited every time. And this will also reduce the depth of penetration.

So, shallow penetration, low heat input very small bead reduced penetration will be reducing the transfer of the carbon from the base metal to the weld metal. And that is how it will be reducing the possibility for the higher CE higher hardenability and that in turn will facilitate the formation of the softer heat affected softer weld metal. We cannot do in this case much with the heat affected zone but of course using suitable filler we can adjust the properties of the weld metal favorably, so that unnecessary cracking tendency of the weld metal is reduced.

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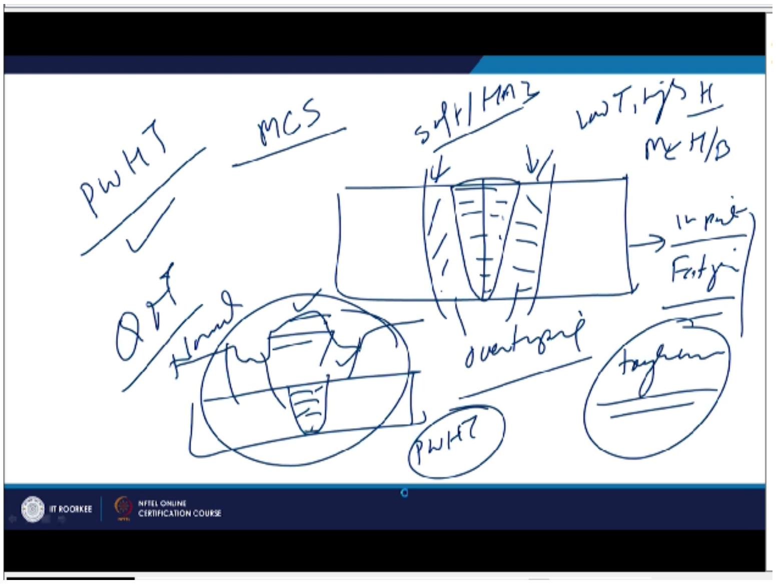

There is then we have to see the post weld heat treatment which can be given in case of the medium carbon steel weld joints. So, as I have said as far as the post weld heat treatment is concerned after the welding like this. In medium carbon steels which is having the tendency for formation of the low toughness, high hardness, heat affected zone having the martensite hard and brittle martensite.

So, these all these are unfavourable things as far as the performance of the weld joint is concerned and especially if the weld joints are to be used for the dynamic conditions. Where impact loading is occurring or the fatigue loading is will be taking place during the service then it is important that suitable toughness is induced. And to induce this toughness the post weld heat treatment becomes an important step.

So, but another there is another aspect like say this is steel is quenched and tempered condition or the normalized condition. So, the steel when it is in quenched and tempered condition when subjected to the welding the additional heat application in the heat affected zone causes the over tempering. And over tempering medium carbon steel in quenched and tempered conditions will be leading to the formation of the soft heat affected zone.

So, if the steel is not in Q and T conditions and it is in normalized condition then it will be leading to the hardening. And if it is in the Q and T conditions then due to the over tempering

HAz will be subjected to the softening. So, what will be having in this typical situation after the welding due to the martensitic transformation weld will be harder. But due to the over tempering HAz will be softer and then the base metal will be stronger.

So, the softer HAz and harder weld metal, so this is kind of heterogeneity in the properties which will be existing. And if you want to restore the properties like good toughness of the weld and improved properties of the soft and heat affected zone, post weld heat treatment becomes mandatory. So, that it helps in homogenization of the structure as well as making the properties more uniform. So, that the issues related to the softening of the heat affected zone can be addressed.

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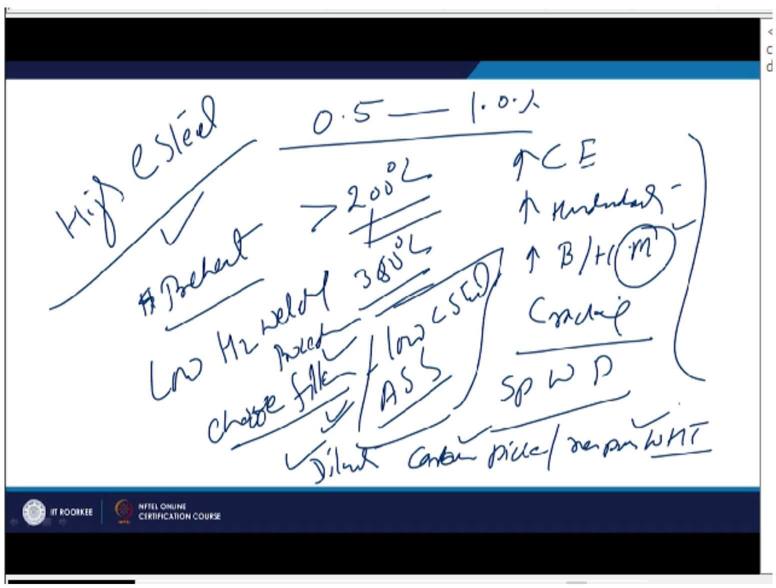

Then we have the high carbon steel, now high carbon steel has the carbon content in the range of 0.5-1% which is really extremely high. And if the carbon content is so high CE is also high, high hardenability, extremely hard and brittle and hard martensite is formed. And because of this very sensitive for cracking, so we really need very special welding procedure for welding of the high carbon steel.

So that these issues can be sorted out and the primary things that we have in our hand is use of the controlled preheat. So that the formation of hard and brittle martensite can be formed and other kind of the preheat which is used that is normally greater than 200 degree centigrade. So

200-300 or 350 degree centigrade preheat can be used as per the carbon equivalent and the section thickness joint restraint conditions suitable preheat to be established.

And then definitely will be using the low hydrogen welding procedures, so that not just the preheat but the low hydrogen consumables, low hydrogen welding processes are used. So that the minimum possible hydrogen is introduced in the weld metal during the welding and after that we have to choose the suitable filler so, for as far as filler is concerned now will low carbon steel filler is used.

And the austenitic stainless steel filler is used, so basically the softer fillers are used. Because we need to deal with the issues relate with the dilution as well because high carbon will be going into the weld metal, will be causing the problem with the hardenability. So, softer fillers are used of the low alloy steels, low carbon low alloy steels are the austenitic stainless steel. So, that we can take care of the issues related with the carbon pickup response to the heat treatment and the dilution.

So, the selection of the filler becomes crucial in light of the dilution pickup of the carbon which is going into the weld metal and the way by which response to the heat treatment or the response to the weld thermal cycle of the base metal is being affected.

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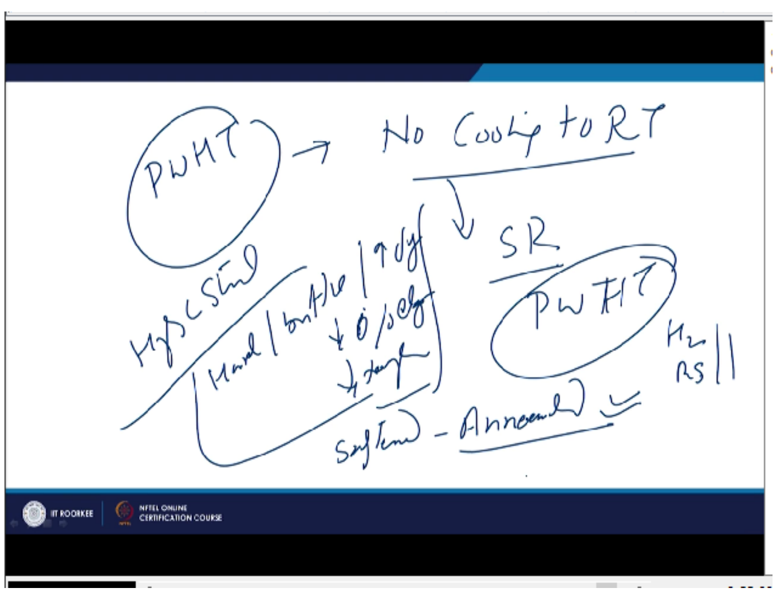

So, now as I have said for post weld heat treatment after the welding no cooling to the room temperature. But direct a stress relieving treatment and the post weld heat treatment is preferred, so that all undesirable aspects related to the hydrogen residual stresses can be taken care of. But whenever the high carbon steel is welded we know since it is very hard, brittle, high yield strength, soft low ductility, low percentage, elongation, low toughness.

So this kind of combination the property is really hard to weld very difficult to weld. So, in order to make them suitable for welding they are softened. Softening of course will be performed by annealing. So, steel is annealed high carbon steel is annealed, so that it is having the softer phases is like coarse pearlite having the lower hardness, lower brittleness reasonably good elongation and the toughness.

So, the high carbon steels need to be welded in the annealed condition even if the parts which are to be repaired need to be annealed. So that the repair welding can be performed effectively, so the most important thing in welding of the high carbon steel is the proper welding procedure is to be established. It should be tested on the coupons before performing the welding on the actual component.

Now I will summarize this presentation, in this presentation basically of talked about the weldability issues related with the medium carbon steel and the high carbon steel. And since both the steels are of the high hardenability because of the higher carbon equivalent, so the proper procedure for the welding must be established. So that the various issues can be taken care of, thank you for your attention.