Weldability of Metals
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Lecture-15
Weldability of Low Carbon Steel and Mild Steel

Hello I welcome you all in this presentation related with subject weldability of metals and you know that we are talking about the weldability of steels. And there are 4 broad categories of the steels in the carbon steels, so if we talk of the carbon steels.

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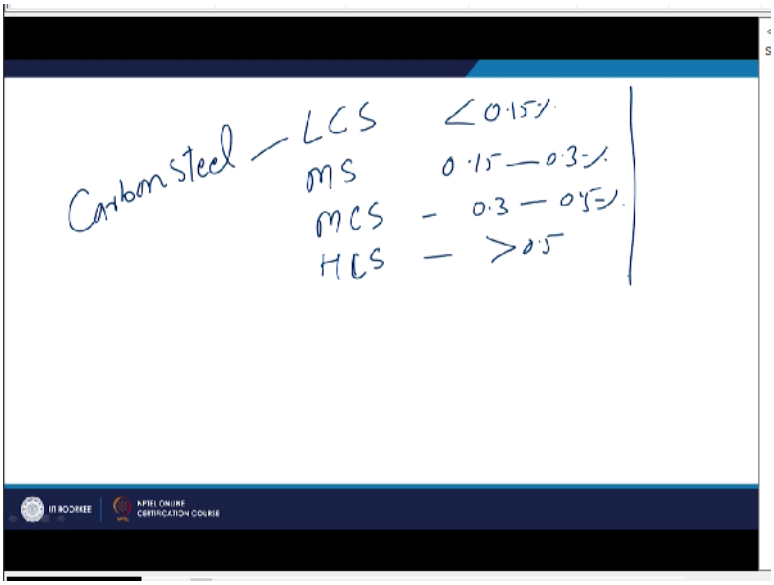

There are 4 types of the steels, one is the low carbon steel where carbon content is less than 0.15%. Then we have the mild steel where carbon content is found about 0.15-0.3% and then medium carbon steel where it is in the range of 0.3-0.5%. And high carbon steel are greater than 0.5%, so according to the carbon content this broad classification is and as the carbon content increases the weldability of the steel in general decreases.

But still we have to weld the different types of the steels, so which kind of the weldability or the issues related with the welding are offered by the various type of the steels that is what will be talking under the weldability of the carbon steel. So, in this presentation basically I will be talking about the weldability of low carbon steel first.

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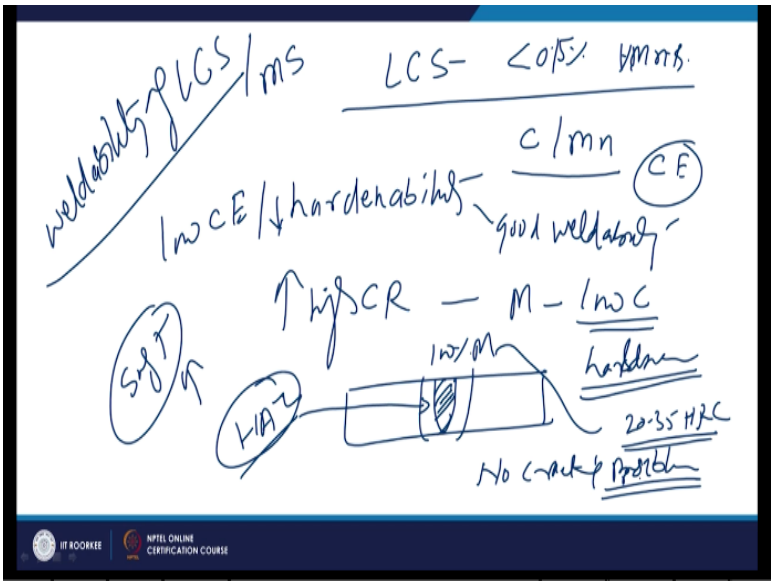

And then I will talk about the weldability of the mild steel, so as I have said the low carbon steels have the carbon content normally less than 0.15%. And the manganese content is about 1%, so since both carbon and manganese concentrations are low. And therefore the carbon equivalent associated with this such kind of the steels is also very low. So, due to the low carbon equivalent this type of the steels offer the low hardenability.

And the reduced hardenability associated with this leads to the very good weldability. Because even if the very high cooling rate conditions experienced during the welding both in the weld metal or in the heat affected zone. The very high cooling rate conditions which may be leading to the development of the martensite. But this martensite becomes of the low carbon content and that is why the hardness of such type of the martensite is not very high.

In some of the cases when the cooling rate is extremely high leading to the complete 100% martensite transformation. Then hardness may range from 20-35 HRC but such a high hardness may not be that much trouble some and the cooling rates which are experienced during the welding of low carbon steels in the heat affected zone are certainly lower than what will be observed in the weld metal.

So, the lower cooling rates being experienced in the heat affected zone during the welding of low carbon steels in any case will be the soft not as high as hard as that of the weld metal. And that is

why there is no cracking problem with this kind of with the low carbon steels. But there is another issue which is associated with the low carbon steels.

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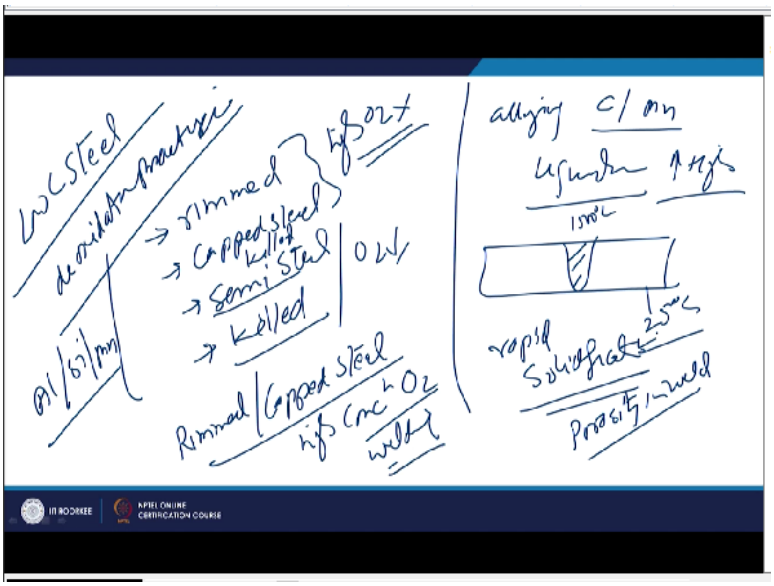

Since the alloying concentration alloying element in form of carbon or the manganese is very low that is why the liquidus temperature of such steels is high. And therefore the weld tends to solidify very rapidly because the molten metal will be of the temperature say of 1500 degree centigrade. And it will be cooled very rapidly under the welding conditions where the plates initial plate temperature is 25 degree centigrade.

So this will be leading to the rapid solidification, so the another issue which is related with the rapid solidification is the development of the pores or porosity in the weld metal. But not in all types of the low carbon steel this problem is observed, low carbon steels based on the deoxidation practice used at the manufacturing stage. These are grouped as rimmed steel and capped steel, semi-killed steel and killed steel.

So this oxidation is carried out at the manufacturing stage using the suitable deoxidizers like aluminium, silicon, manganese and when this is not done at all then the low carbon steel will have the high oxygen concentration in the steel itself while in case of the semi-killed steel or killed steels the oxygen concentration is reduced through the deoxidation using aluminium or silicon or manganese kind of elements.

So when the rimmed or capped steel which is having the high concentration of oxygen when this is subjected to the fusion welding.

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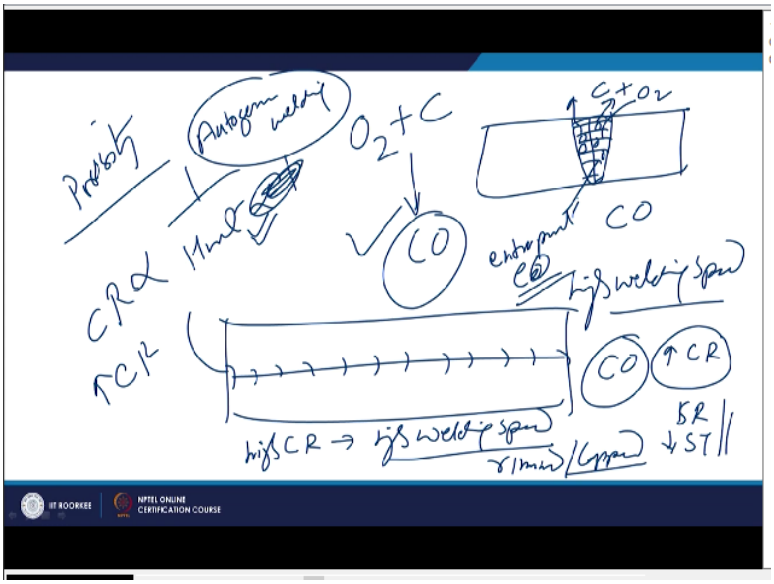

Then we come across the problem of the porosity what is the reason behind high oxygen concentration present in the base metal in the dissolved state. So, in after fusion of the faying surfaces the oxygen present in the base metal reacts in the molten state now reacts with the carbon. And it forms the carbon monoxide, so see oxygen reacts with the carbon to form the carbon monoxide.

Since the high cooling rate experienced by the weld metal due to the high melting point coupled with the high welding speed. Like say the welding is being performed by moving the heat source more rapidly, so the net heat input is reduced and reduction in HN that is net heat input due to the increase of welding speed. The cooling rate is increase because heat input is the cooling rate is found inversely proportional to the H net.

So, if the heat input is reduced and this in turn increases the cooling rate. So, the 2 aspects the faster extraction of the heat from the weld metal coupled with the higher cooling rate uh due to the higher welding speed. If 2 these combinations are present during the welding of the low carbon steels which are rimmed or capped type.

Then this carbon monoxide due to the high cooling rate conditions weld metal experiencing the higher solidification rate, reduced solidification time. This situation leads to the entrapment of the carbon monoxide gas in the weld metal itself because it does not get enough time for escaping and this leads to the entrapment of the Co in the weld metal itself that is how it leads to the development of pores.

So high cooling being caused by the high welding speed during the welding coupled with the rimmed or capped steel having the higher concentration leads to the formation of co. And eventually due to the high cooling rate entrapment of the co leads to the development of the pores, so in general this is the commonly encountered problem in case of the autogenous welding of the low carbon steels or the rimmed or capped type of the low carbon steels.

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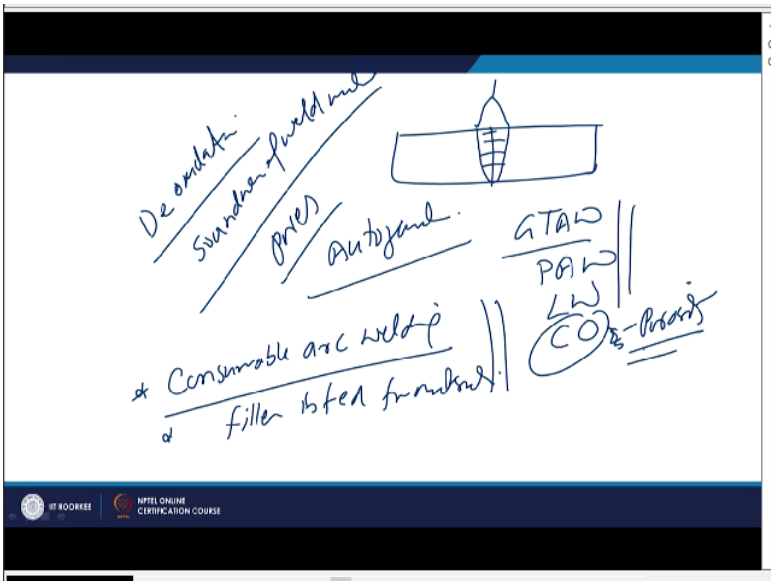

Because in autogenous welding we simply supply the heat from the external source for facilitating the fusion of the faying surfaces. So, that whatever oxygen is present in the base metal or in the molten metal that reacts with the carbon to form carbon monoxide. So, it so that the deoxidation the type of deoxidation practice used in manufacturing of the low carbon steels affects the soundness of the weld metal through the development of pores.

Especially in case of the autogenous welding and this a type of welding is performed using the non-consumable welding processes like gas tungsten, arc welding plasma, arc welding or laser welding. So where the electrode is not consumed during the process as a inherent part of the process but if it is required to feed the filler metal. And it will be fed from outside in form of the filler rod.

So, when we use the consumable welding process, consumable arc welding process or filler is fed from outside. Then in both these cases the problem associated with the formation of co and the porosity is to some extent can be addressed.

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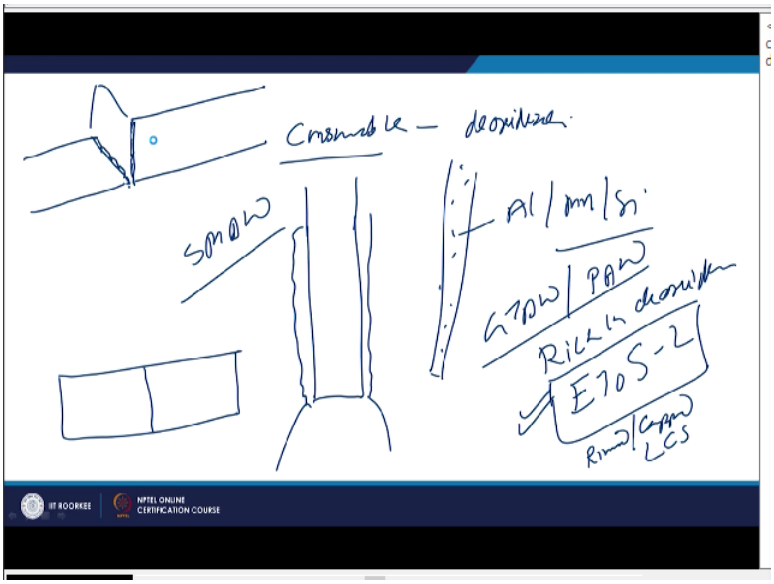

And what is that logic when the consumables are used, so the consumables will be designed or will be provided with the suitable deoxidizers. Like the electrode itself will be designed to have the suitable deoxidizing elements like aluminium, manganese and silicon or in case of the shielded metal arc welding electrode. The alloying elements can be provided along with the flux.

So that these elements get introduced in into the weld metal to take care of the oxygen present in the weld metal. So that oxygen can be taken care of in order to avoid the formation of the co under development of the pores. So one most commonly used electrode which is used in the gas tungsten arc welding, plasma arc welding which is very rich in deoxidizers is E70S2.

So, this is one typical electrode which can be used in case of the non-consumable arc welding processes, while welding is being done of the rimmed or capped type of the low carbon steels. So the high concentration of the deoxidizers with such kind of the filler will take care of the oxygen dissolved oxygen present in the weld metal to avoid the formation of the pores.

There is another method where the faying surface is are painted with the deoxidizers like this is one base metal and this is another base metal and 2 plates are to be welded. So paint of the deoxidizer like aluminium on the faying surface is done and thereafter welding is perform. So, this aluminium will act as a deoxidizer to take care of the oxygen, so that the issues related with the porosity can be addressed.

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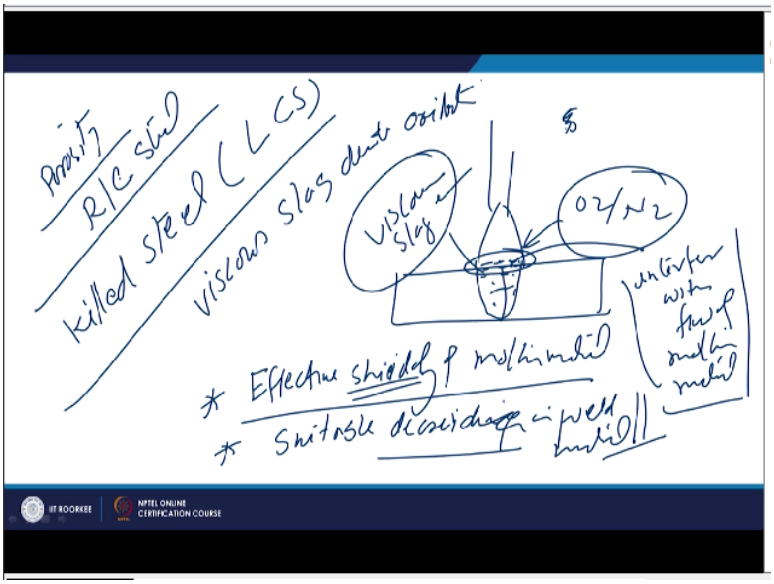

So, the porosity was the main problem associated with the rimmed or capped steels but if we talk of the killed steels or killed low carbon steel. Then the problem is of another kind that is about the formation of the viscous slag due to the oxide formation during the welding. So the killed steels during the welding if the form if the protection during the welding is poor.

So oxygen from the atmosphere or nitrogen from the atmosphere reactive with the molten metal. And forming the viscous slag, so this viscous slag or the impurities or the oxides which are being formed at the top surface of the molten metal this viscous slag or the viscous oxide layer which is

being formed at the top surface layer will interfere with the flow of the molten metal during the welding.

So the flow pattern is adversely affected during the welding, so this can lead to the development of the weld defects associated with the poor fluidity or poor flow pattern of the molten metal. So, in order to take care of this there are means to avoid the formation of the viscous slag or to avoid the formation of the oxides which are in of the high viscosity adversely affecting the flowability of the molten metal.

There 2 things which are try one is to have the very effective shielding of the molten metal. So if the shielding is not effective then only these oxides will be formed due to the interaction with the atmospheric gases of the molten metal. And that will be leading to the formation of the viscous slag or the molten layer which is of the higher viscosity due to the formation of these oxides. Another thing is that addition of the suitable deoxidizers in the weld metal.

So these deoxidizers will be reducing the amount of the viscous oxides which are being forms and the characteristics of the slag which will be formed will be more favorable as compeered to that of the viscous slag which will be formed. So, addition of the suitable deoxidizers as well as effective production helps to avoid the formation of the viscous slag at the top of the molten metal which otherwise adversely affects the flowability and increases the tendency for the defect formation.

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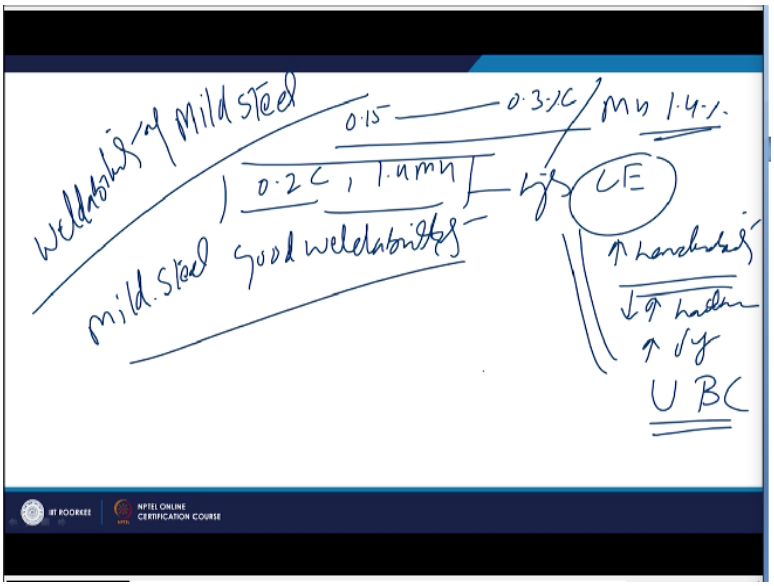

Now we will talk about the weldability of mild steel, so as I have said the mild steel has much higher carbon content range of like say 0.15-0.3%. And also the manganese content can also higher like 1.4%, so like 0.2% carbon, 1.4% manganese and these combination itself can lead to very high carbon equivalent increased hardenability and so increased hardness and the yield strength.

And if there are lot of inclusions and the conditions are more favourable with regard to the restrain then it can cause the under bead cracking tendency. So, it can be susceptible under the certain conditions, otherwise the mild steels of a good weldability. So, will talk in detail about the various weldability related aspects of the mild steel.

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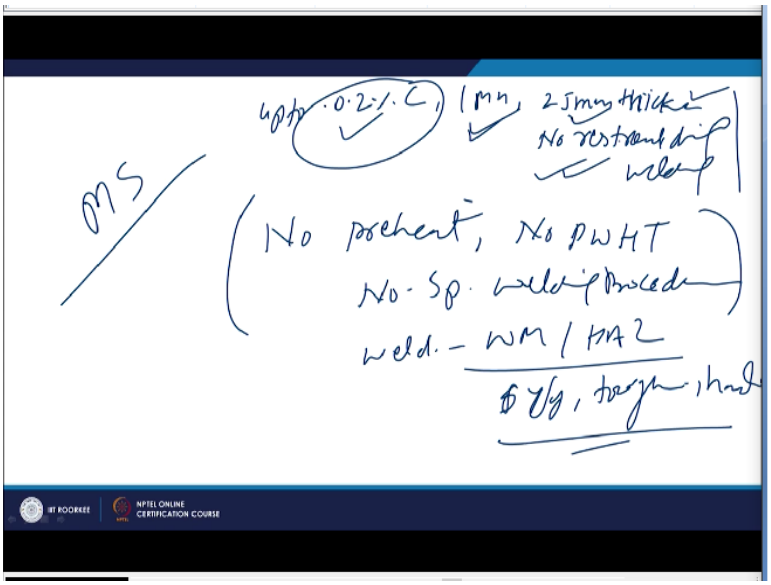

Normally these up to 0.2% carbon and 1% manganese, 25 mm thickness, no restraint during the welding. So, if these are the conditions like carbon content, manganese content 25 mm thick plate no restraint during the welding of the mild steel. In that case primarily no preheat, no post weld heat treatment is needed and no special welding procedure is needed.

Because whatever the weld is developed the properties of the weld in weld metals as well as heat affected zone. They are still favourable with regard to the yield strength sigma y toughness and the hardness. So, the issues related with the mild steel or not much for when it is having the carbon content of 0.21% manganese up to 25 mm thickness. And the welding is performed in without restraint condition.

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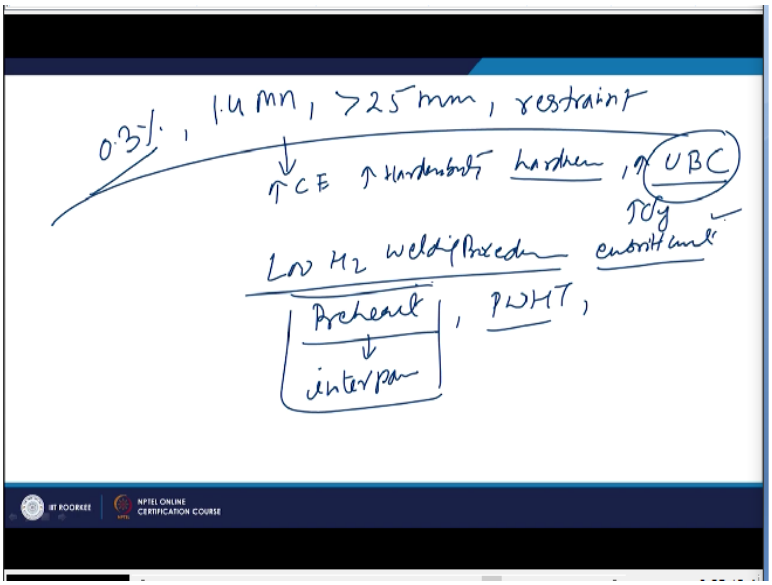

But the problems will arise on the other extreme like the mild steel is having the carbon content of 0.3%. And the manganese is of 1.4% and the welding is to be done of thickness greater than 25 mm and so if these are the 3 conditions and one more the welding is to be performed under very restraint conditions. So, if these are the conditions for the welding are present than as for the compositions and the fabrication conditions.

Then there can be the various problems. Because the high carbon as well as high manganese leading to the higher carbon equivalent higher hardenability and so the formation of the martensite of the high hardness which in turn will be increasing the under bead cracking tendency of this kind of the steel, while offering really good yield strength.

So, **so** in order to avoid the under bread cracking and the possibility of the embrittlement to avoid both these it is required sometimes to use the low hydrogen welding procedure which means will be using all such type of the consumables which will lead to the minimum hydrogen content in the weld metal very effective cleaning, preheating, post heating as per the requirements. So that the hydrogen really can be taken care of suitable preheat.

Now the preheat temperature may not be very high it may be like 40, 50 degree centigrade only and then post weld treatment. So that if there is a hydrogen it can be diffused out to avoid any possibility of the cracking subsequently. So, and similarly the post weld treatment and then

preheat is being applied it is always ensured that after one pass other passes are also carried out at the same temperature. So preheat temperature and interpass temperature both need to be maintained at the same level.

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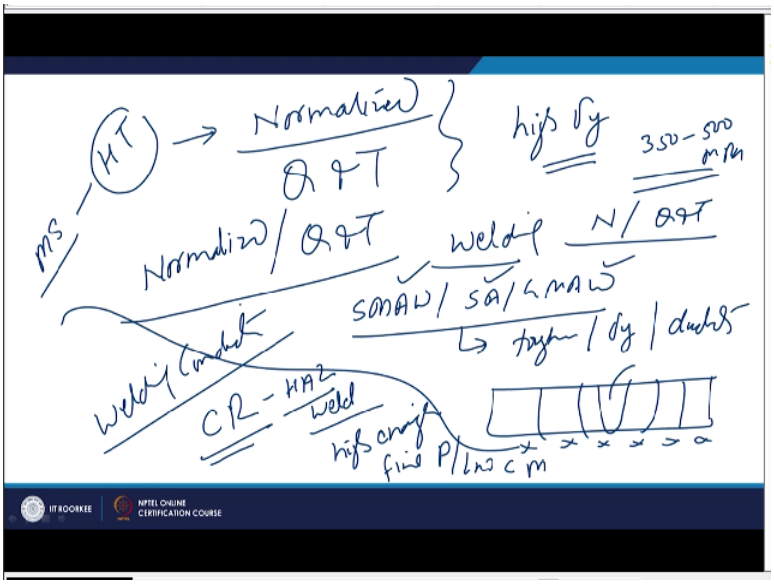

Now these mild steels are mild steels are found in various heat treatment conditions, normal heat treatment conditions in which mild steels is found is the normalizing or normalized condition and quenched and tempered condition. These steels are designed means these heat treatment is primarily given, so that as far the carbon content high yield strength sigma y can be ensured.

And so that they are of range of the yield strength from 350-550 MPA. Now, so which means that it may be required to perform the welding in various heat treatment conditions like normalized or Q and T conditions. So, if we talk of the kind of the conditions means welding procedure to be used when the steels is either in normalized or Q and T condition . In normally all standard welding procedures like SMAW, SAW or GMAW welding of such kind of the steel can normally be performed without any special precaution.

Because it offers reasonably good toughness, yield strength and the ductility combination and the properties mostly in the weld heat affected zone and the base metal or almost similar kind. But special precautions are needed when we want that these are almost same across the weld joint

then we need special precautions and special steps. So, it is normally easier to perform the welding using this standard procedures.

If almost acceptable weld is needed in case of the normalized and quenched in tempered steels. Because the kind of the welding conditions experienced by the steel during the welding like cooling rate conditions, experienced in the heat affected zone as well as in the weld region. These are high enough using when the welding is performed using like SMAW, SAW or GMAW the cooling rate is high enough to produce the fine pearlitic structure or low carbon martensite.

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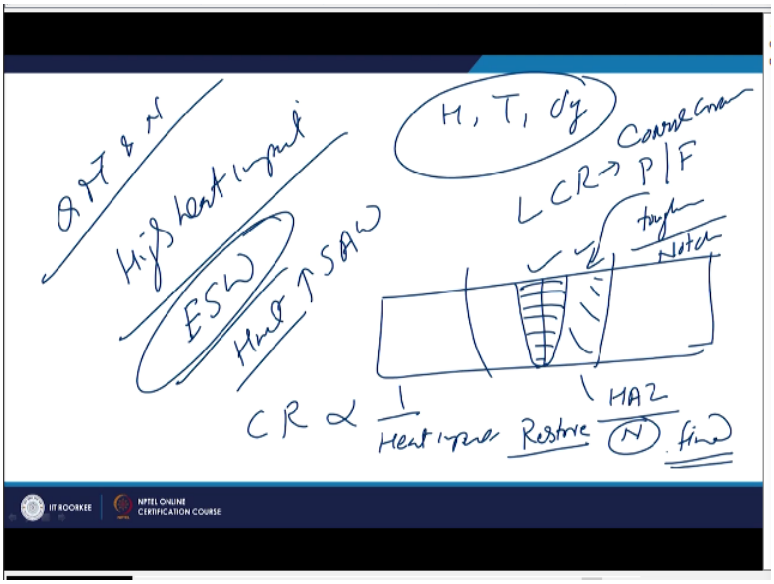

So, these will not be deteriorating the properties appreciably and will be leading to the good combination of the hardness, toughness and the strength. So, most of the common welding processes can be easily applied but if we want exactly same kind of the toughness in the weld base metal and heat affected zone. Then we need precautions for developing the suitable welding procedure.

In some of the case when like the steel is welded either in Q and T conditions are in normalized condition using the high heat input welding process like electro slag welding or extremely high welding conditions like welding current and the voltage. And the welding speed combination is such that the H net is really very high in case of the SAW then high heat input conditions as I have said cooling rate is found inversely proportional to the heat input.

So, if the input is very high during the welding of the steels mild steel in Q and T are normalized condition. Then the cooling rates will be very low and if the cooling rate very low cooling rate is experienced either in the weld metal zone or in the heat affected zone. So, low cooling rate in the weld metal or in the heat affected zone especially during the welding of the electro slag welding process during the welding by the electro slag welding process.

It will be leading to the low cooling rate which will be causing the or developing the very coarse grain pearlitic or ferritic structure. So, coarse pearlitic and ferritic structure in the weld metal and the heat affected zone more specifically in the heat affected zone lowers the toughness of the weld joint increases the notch sensitivity of the weld joint reduces the strength so, in order to in under such conditions.

In order to restore the mechanical properties in the weld as well as the heat affected zone post weld heat treatment may be necessary. So, we may perform normalizing after welding, so that the grain structure can be refined, fine grain structure in the weld as well as heat affected zone can be produced. So, that a toughness strength can be enhanced and if the post weld heat treatment due to the fabrication conditions is not possible.

Then it is ensured that after the welding the weld metal and the heat affected zone is cool at sufficiently high rate. So, that the fine grain structure can be realized , so now I will summarize this presentation, in this presentation basically I have talked about the weldability issues related with the low carbon steel and the mild steel. In case of the low carbon steels there are 2 issues mainly one is the porosity formation.

And another is the viscous slag formation, while in case of the mild steel in general the weld is good. But if the welding is to be performed under the restraint condition carbon content is high manganese concentration is also high. Then we may require the suitable preheat as well as post weld heat treatment further details about the weldability of the mild steel I will be talking subsequent presentations, thank you for your attention.