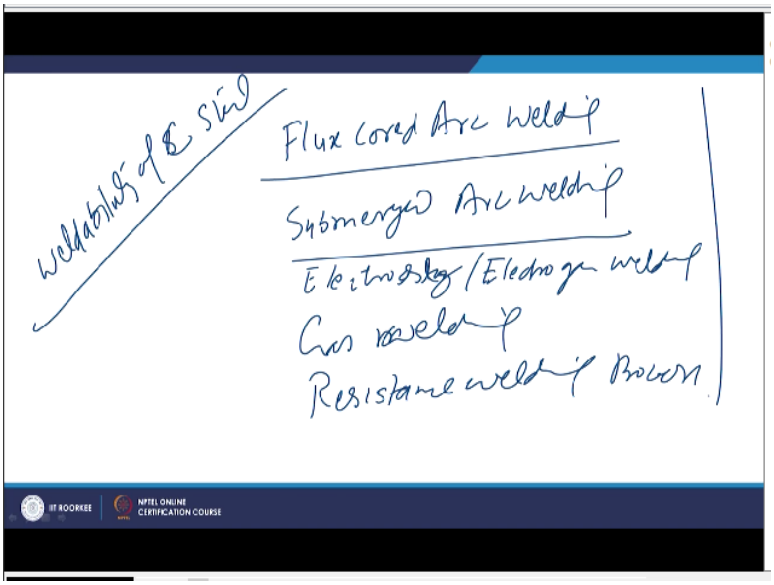
Weldability of Metals
Prof. D K. Dwivedi
Department of Mechanical and Industrial Engineering
Indian Institute of Technology-Roorkee

Lecture-18
Weldability of Carbon Steels and Welding Processes-II

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 the carbon steels. So, in the previous presentation I have talked about the weldability of carbon steels with respect to the shielded metal arc welding process and the gas shielded arc welding processes which includes like gas metal arc welding, gas tungsten arc welding and the plasma arc welding.

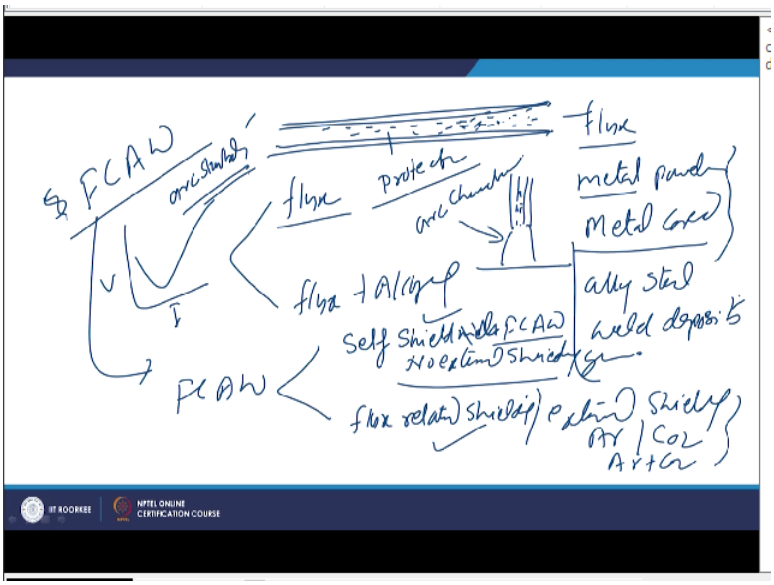
In this presentation basically will be talking weldability of carbon steels when they are welded by the different processes like flux code arc welding.

(Refer Slide Time: 01:24)



Then submerged arc welding, then the gas welding and electro slag and electro gas welding and resistance welding processes. We will try to see what are the things which we can cover in this presentation.

(Refer Slide Time: 02:07)



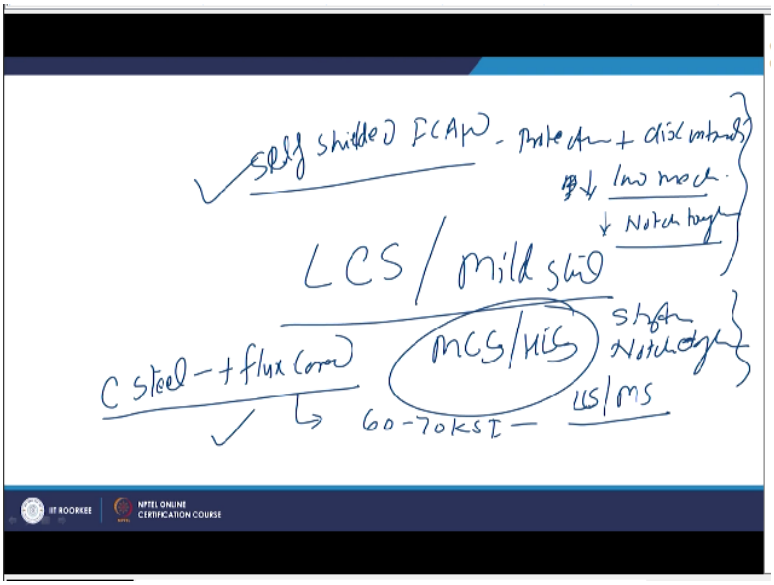
So, will start with the FCAW flux code arc welding basically this welding process uses the consumable electrode where the one electrode is there in the tube form. And this tube can be filled just with the flux and also with the metals in the powder form. So, in that case it is termed as metal code and this one is used for depositing the alloy steel weld deposits. So, there are 2 variants as far as this one is concerned like electrode can be filled just with the flux or the flux+alloying elements also can be filled in.

Then there is another variant of the FCAW wherein we may use only the self shielded FCAW, no in this process no external shielding gas is provided. Whatever the flux is there inside that is **t** thermally decomposed by the arc during the welding and thereby it provides the protection to the molten metal from the atmospheric gases. And there is another variant in which in addition to the flux related shielding external shielding using argon or CO2 or argon+CO2 mixtures is used.

So, there are 2 variants where no external shielding gas is used that is self shielded FCAW and there is another one where argon or argon carbon dioxide mixtures can be used to provide the more effective shielding to the molten metal. So, these are the 2 variants which are used we know that the flux role of the flux is primarily to provide the protection. But some of the constituents also or also there which will be affecting the charged particle density in the arc environment.

Like this is the flux code, this is the arc, so the constituents present in the flux effects the arc characteristics because of variation in the charged particle density being affected by the flux constituents. So, VI characteristic of the arc is affected by the flux composition and which in turn determines the arc stability. So, apart from affecting the protection being provided to the weld pool the flux constituents which are present in the core of the tubular electrode.

(Refer Slide Time: 06:16)

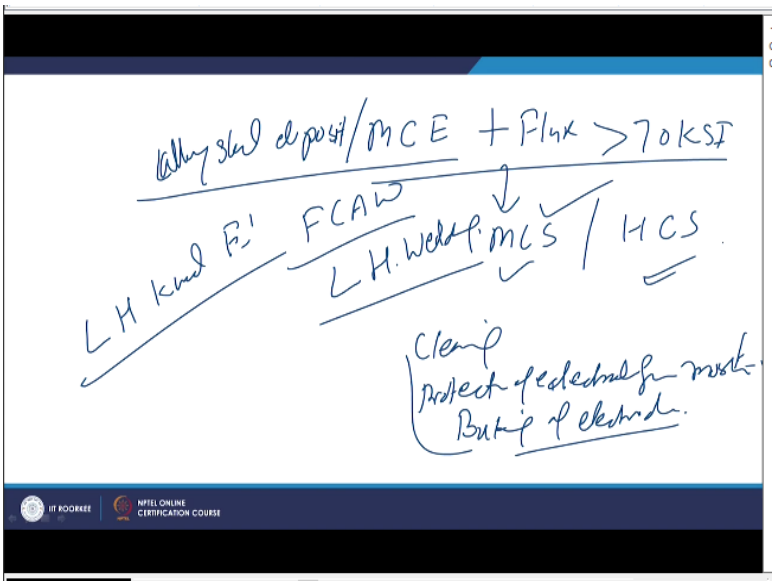


The arc characteristic is also affected and if we see in those cases where self shielded FCAW is used protection to the weld pool is not that effective. And that is why there are discontinuities in the weld metal which in turn increase the tendency to have the defects in the weld joint and these in turn lower the mechanical properties more specifically. These reduce the notch toughness of the weld metal.

And that is why this variant of the FCAW is found fit for low carbon steels and the mild steel only which shows great tolerance to the discontinuities because of the low yield strength and the low ductility. But for but if the strength requirement if the strength notch toughness requirement are not that serious. Then it can also be used for medium carbon steels and the high carbon steels.

On the other hand, so the carbon steel tubular electrodes with the flux code only are designed for strength of 60-70 KSI good for low carbon steel and the mild steel applications means joining. If the strength criteria is satisfied for the medium and high carbon steels also then this can be used.

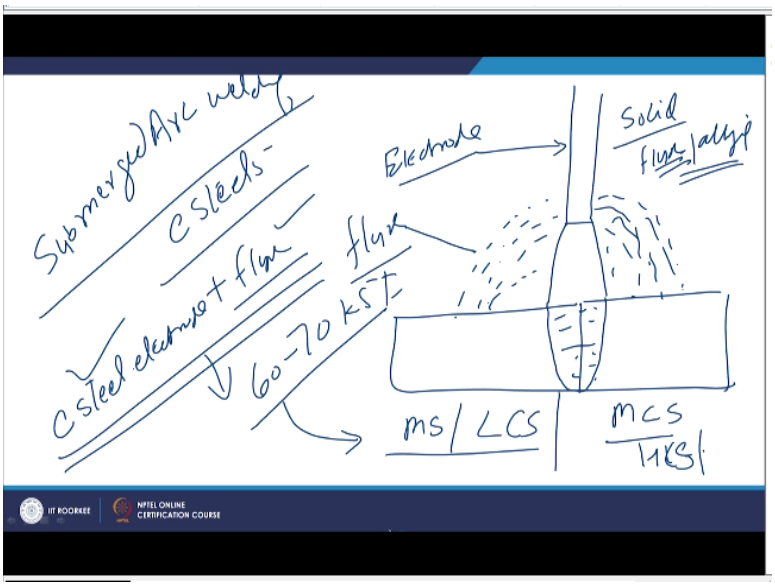
(Refer Slide Time: 08:31)



On the other hand the alloy steel deposits in case of the metal code electrodes+the flux, these electrodes are designed to have the strength greater than the 70 KSI. So, that it matches with the strength requirement of the medium carbon steels and high carbon steels. So, metal code electrodes are found fit and more effective for the medium and high carbon steels as compared to the self shielded FCAW electrodes.

These electrodes are mostly the low hydrogen kind of the electrodes and so the FCAW offers the advantage of the low hydrogen welding conditions provided, other aspects like cleaning protection of the electrodes from moisture. And if it has been exposed then proper breaking of the electrodes, in order to drive out all the moisture if it has been absorbed by the electrodes. So, that the low hydrogen deposits can be developed, so these are fit for medium as well as high strength steel requirements.

(Refer Slide Time: 10:27)



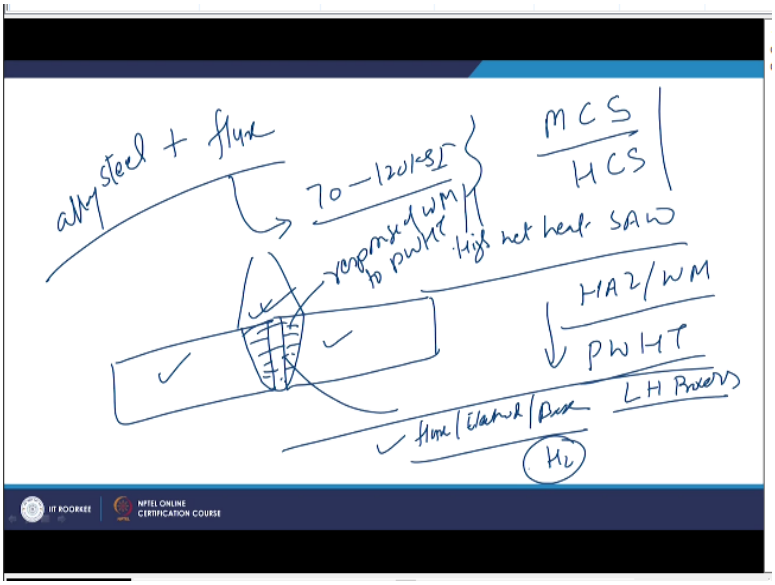
Now will be talking about the submerged arc welding and weldability of the carbon steels, so we know that the submerged arc welding process. Basically the process works in like this where there is any consumable electrode and the components to be joined there is a arc. Arc is fully submerged under the granular flux, so this and heat generated helps to melt the faying surfaces. And on solidification we get the joint required.

So, when we are using the submerged arc welding there are constituents the main components are like the granular flux and the electrode bare electrode. This electrode can be solid or can be in tabular form where flux is filled in order to have flux or the alloying elements in order to have the required the composition of the weld metal. Mostly the carbon steel electrodes+the flux composition with regard to the basicity as per the constituents present in the flux.

The these have been designed for the strength acquirement of 60-70 KSI, so the carbon steel electrodes and the flux compositions have been developed for all weld metal properties means the UTS of 60-70 MPA. So, that reasonable level of the strength for joining of the mild steel and the low carbon steels can be facilitated. And if the strength requirements are satisfied then even this can be used means carbon steel electrode+flux combinations can also be used for medium carbon steel as well as high steels .

Apart from this there is another kind of the electrode which is possible like the either the solid wire or the tubular electrode is made of the alloy steel+ the flux composition.

(Refer Slide Time: 13:14)



This kind of the combination also has been identified for the strength requirement greater than the 70 MPA. So, that 70-120 KSI strength can be achieved in all weld deposits, so that it can be used for high strength steels like medium carbon steel and high carbon steel. At the same time it is also seen that due to the high net heat input associated with the SAW may cause the damage to the HAz properties as well as to the weld metal properties.

So, it may be required to perform the post weld heat treatment, so that the required structure in the weld as well as heat affected zone can be realized in order to have the required combination of the mechanical properties we need to see at this stage like the base metal are being fused and getting mixed with the electrode material. So, whatever weld metal is being achieved it should respond means response of weld metal to the PWHT post weld heat treatment should satisfy the requirement of the heat treatment.

So, that the improvement in weld as well as heat affected zone properties after the post weld heat treatment can be realized. If there is a mismatch with regard to the composition and the response to the heat treatment of the base metal and weld metal. There we may find the despite of the post

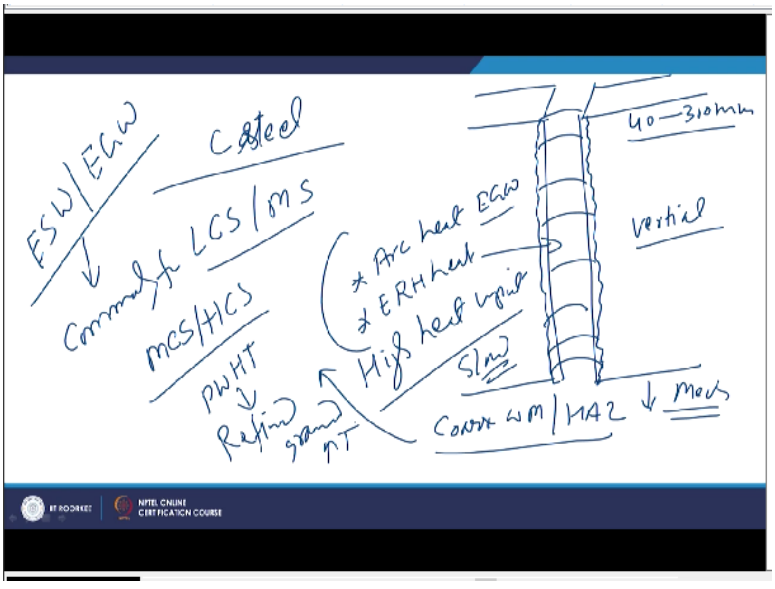
weld heat treatment the weld metal is not able to realize the properties as expected this may be on the 2 higher side or on the 2 lower side.

Like if the alloying content in the weld metal is more than the base metal then due to the high hardenability it may lead to the cracking embrittlement and the reduced toughness, on the other hand reduced concentration of the alloying elements may lead to the reduced strength as well as reduced hardness of the weld metal. So, we need to see the composition of the weld metal is adjusted in such a way that it is response to the heat treatment is similar to that of the base metal.

So, that required combination of the mechanical properties is realized. These processes are also can be design to have the benefit of the low hydrogen fabrication conditions. And for that purpose flux electrode base metal all these must be protected clean prepared properly. So, that there is no moisture, there is no impurity and the oil paint, dust extra, which on subsequent the thermal decomposition may offer the hydrogen to the weld.

So, in order to have the low hydrogen benefit associated with this process efficient and effective preparation and cleaning and storage maintenance extra, of the consumables is required.

(Refer Slide Time: 17:09)



Now we will see the another variant of another welding process that is the electro slag welding or electro gas welding of the carbon steels. These are the 2 processes which use the 2 principles,

1 is the arc heating, in case of the electro gas welding and electrical resistance heat through the flow of current through the molten slag for generation of the heat. So, that the faying surfaces of the base metal can be brought to the molten state.

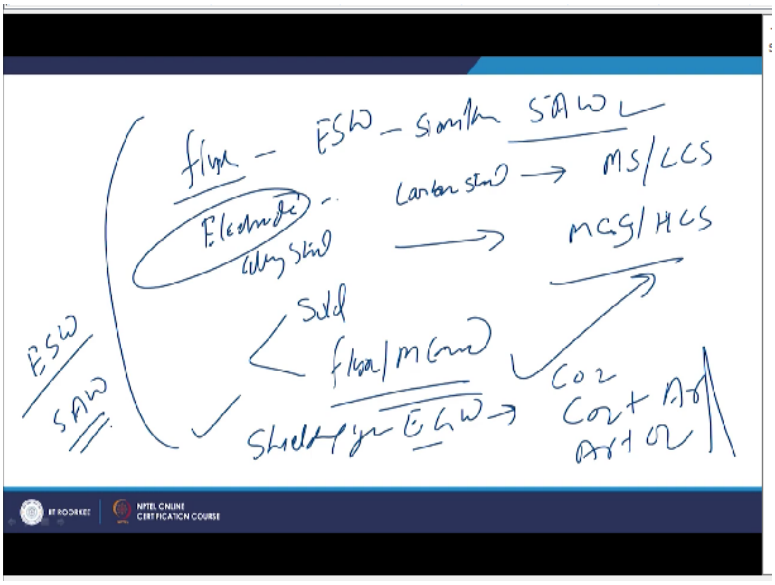
So, this is like the plates to be joined or kept in vertical position in vertical plane and these are the faying surfaces in front view this will be the thickness direction. So, basically thick plates are welded using this process of thickness mostly ranging from 40-300 mm in thickness. And this is a single pass welding process which is performed in one go the typical characteristic of this process is that it supplies lot of heat.

So, it is a high heat input process it is slow as for as the speed at which the weld metal is deposited during the welding process. So, because of this high heat input associated with this process we get very coarse weld metal as well as heat affected zone. And these properties deteriorate the mechanical performance of the electro slag or electro gas welded joints.

Now will see what are the things which are used for this purpose, so mostly both these processes are very commonly used for low carbon steels and the mild steel joining purpose. Because the compromise with the weld and heat affected zone properties after the high heat input is not much as compared to what we see in case of the medium carbon steels and the high carbon steels.

But in that case when these are applied for medium carbon steels and the high carbon steels we require the post weld heat treatment. So, that the coarse grained structure in weld and heat affected zone can be refined for and this is a basically realized through the normalizing. So grain refinement is realized through the normalizing in order to improve the toughness of the weld as well as heat affected zone.

(Refer Slide Time: 20:42)



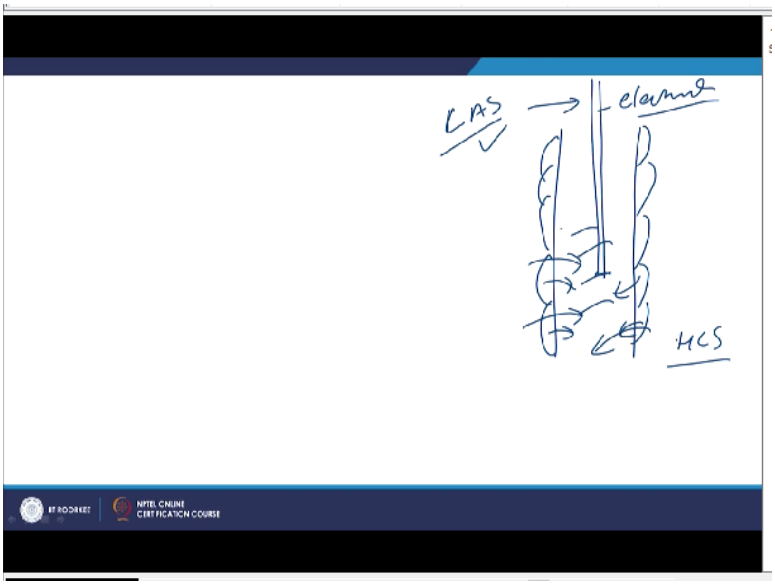
So, as far as the flux is concerned, the fluxes used in the electro slag welding or similar to that of the submerged arc welding. And the electrode is also of the similar kind what we have seen in case of the electro in case of the submerged arc welding. So, like the carbon steel electrodes are mostly used for mild steel and low carbon steels and maybe alloy steel deposits can be used for the medium carbon steels and high carbon steels.

So that will be satisfying the requirement of the strength as well as the response to the heat treatment, for this purpose as we have talked in case of the SMAW. We can use both solid as well as flux or metal code electrodes, so metal code electrodes are mostly used for the carbon steel and the medium carbon steel and high carbon steels where alloy weld deposits need to be supplied.

And as for as the shielding gas, use of the shielding gas in the electro gas welding processes concerned basically we use the carbon dioxide or carbon dioxide+argon or argon+oxygen mixtures. So, these are the things which can be used for protecting the weld pool from the atmospheric contamination or contamination of the weld pool from the atmospheric gases. So, that unnecessary degradation in the weld metal properties can be avoided.

So, we can say that the electro slag welding is a type of variant of the SAW where flux is a primarily used but the heat generation here is through the flow of current through the molten slag. So, that the fusion of the faying surfaces can be realized.

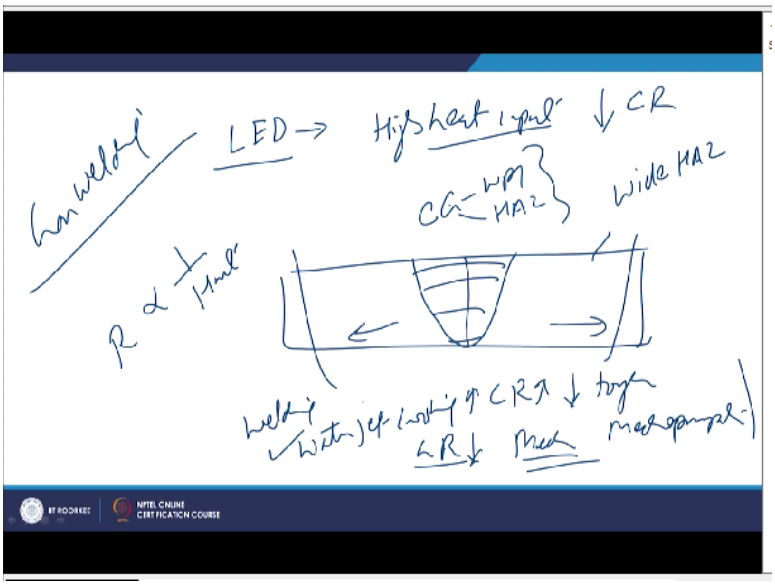
(Refer Slide Time: 23:03)



But since the process is high heat input, so the lot of the base metal will be melting and going into the weld metal. So, we need to see that whatever effect of dilution is there that is considered while selecting the electrode composition. We may select the electrode of the suitable composition but dilution made degrade the properties in either way it can increase the hardness and strength or it may deteriorate the hardness and strength.

For example if we use the low alloy steel filler and which is being used for high carbon steel welding and this carbon getting into the weld pool due to the fusion of faying surfaces will be enriching the alloying low alloy steel with the carbon and making it more sensitive for cracking because of the increased hardenability.

(Refer Slide Time: 24:13)



Now will see the another process that is called gas welding, gas welding is known to be of very low energy density process. So, for the welding of the carbon steels we need to supply very high heat input. Since the flame is spread over a larger area along the weld centerline, so heat is dissipated over the larger area and as a result we need to supply lot of heat first to facilitate the fusion.

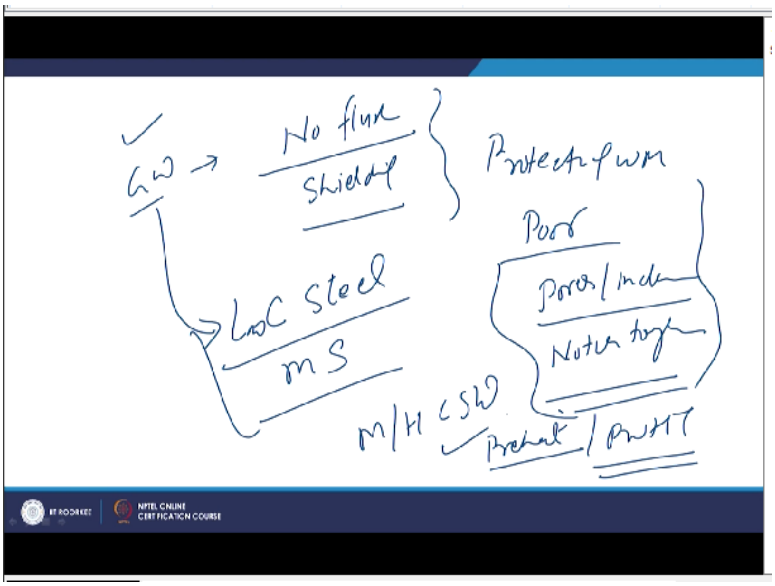
So, when the heat is more the weld area is also more and lot of heat is dissipated to the base metal. And because of this we find very wide heat affected zone since the high heat input leads to the reduced cooling rate. Since the cooling rate is found inversely proportional to the heat input, so higher heat input lower will be the cooling rate. Reduced cooling rate low cooling rates leads to the coarse grain structure in the weld metal as well as heat affected zone.

And such kind of the coarse grain structure in weld metal and affected zone deteriorates the toughness mechanical properties. So, load carrying capabilities, so in order to enhance the load carrying capability of the gas welded joints of the carbon steels. Basically the welding is performed first the welding is performed using the gas flame and then water jet can be used for cooling purpose.

So, that the cooling rate can be increased which can be used for the grain refinement and a grain refinement can help to increase the mechanical properties. So, there is one way to deal with the

issues related with the low cooling rate chain countered during the gas welding. Because of high heat input we may use the water quenching or the jet cooling.

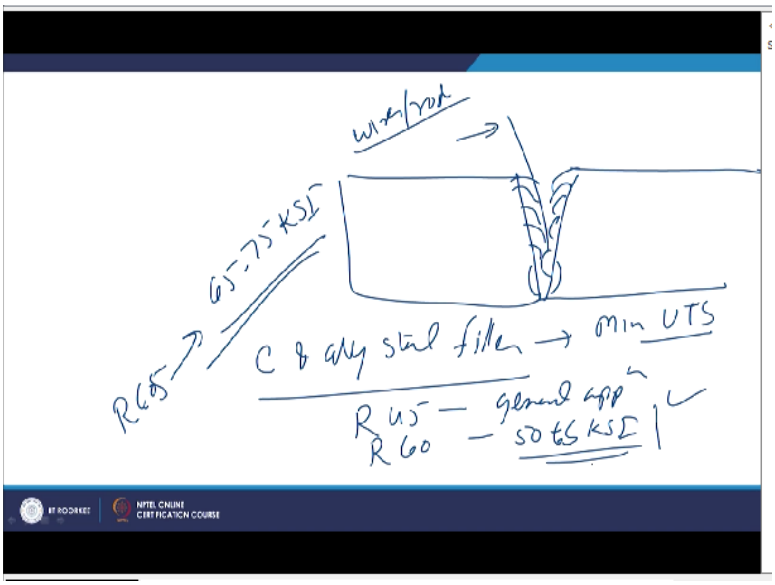
(Refer Slide Time: 26:42)



This was the aspect related with the heat input, at the same time in the gas welding we do not use any flux. There is no flux and there is no specific shielding and that is why the protection of weld metal from the atmospheric gases is very poor. And that is why the weld metal being produced of the carbon steels produced by the gas welding is found very sensitive to have the pores, inclusions. And these in turn will be reducing the notch toughness of the steels.

So, these are generally poor you see these can be tolerated when the gas welding being used for the carbon steel low carbon steel and the mild steel. But if it is to be applied for the medium and high carbon steels then we need to take proper precautions with regard to the preheating as well as post heat treatment. So, that the required toughness can be induced and unnecessary degradation in mechanical properties of the joint can be avoided.

(Refer Slide Time: 28:14)



Now we will be seeing the kind of the fillers which are used like the thick plates when thick plates to be welded we need to prepare the edges. And then using the flame the fusion will be facilitated of the base metal as well as the filler. Metal is to be supplied through the wires, rods, so the filler rods are used. Filler rods will be filling the gap which has been created through the edge preparation for development of joint.

So, both carbon and alloy steel fillers are used just like in GTAW and the plasma arc welding processes. And these are designed based on the minimum ultimate tensile strength, so there are various types of the filler rods which are used for the gas welding. One typical is R45 which is most commonly used for general applications of the welding. There is another one R60 which offers the strength from 50-65 KSI all weld metal strength.

And then there is R65 which offers the strength 65-75KSI, so there are different types of the rods and which can be chosen as per the requirement of the strength and the kind of the base metal which is to be welded, so that there is a matching the strength as well as the matching response to the heat treatment. So now here I will summarize this presentation.

In this presentation basically I have talked about the various weldability aspects of the carbon steels. When the welding is perform using the flux code arc welding, submerged arc welding, electro slag welding and the gas welding process thank you for your attention.