Weldability of Metals
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Lecture-20
Weldability of Carbon Steels and Radiation Welding and Thermal Cutting

Hello, I welcome you all in this presentation related with the subject weldability of metals and in this presentation we will be talking about the weldability of the different types of carbon steels with respect to the radiation welding processes like laser and electron beam welding and then will also see that how the thermal cutting can affect the cutability of the different types of the carbon steels.

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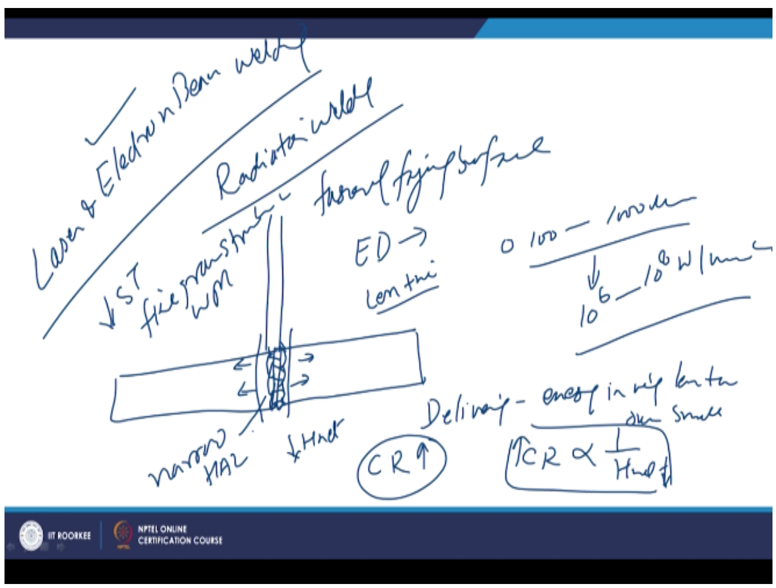

Apart from that if you get time then we will talk about the high strength a low alloy steels. So we know that the laser and electron beam, both these welding processes are known as the radiation welding process because the radiations in form of the laser and the electron beam are used for fusion of the faying surfaces of the metal to be joined and the energy density which is associated with these sources which have the capability to apply the energy over a very small area.

Like 100 micrometer to 1000 micrometers, so lot of energy is supplied over a very small area so an energy density associated with these welding processes extremely high like which can be regulated but for the welding purpose may be 10 to the power 6 to 10 to the power 8 watt/mm square. So this high energy density helps to deliver lot of energy in very less time over very small area.

So it facilitates very quick and fast melting like this the ages of the plates to be welded, the beam will be supplied and this will be facilitating the melting of the melting of the very quick melting of the ages of faying surfaces of the plates will be taking place. So it takes very less time and once the things are fused then obviously the heat source is moved away, so that subsequent solidification leads to the development of metallurgical continuity or the development of joint.

These processes are so fast time is so less that the heat dissipation to the heat affected zone is very less, time for certification is very less because H net is very less for facilitating diffusion and therefore associated cooling rates are extremely high, why because the cooling rate is found inversely proportional to the H net which is being supplied. So very low cooling rate heat input will be leading to the extremely high cooling rates.

So the high cooling rates associated with these processes will be leading to the very less solidification time and which in turn very fine grain structure in the weld metal as well as limited heat delivery, limited heat transfer, limited heat dissipation to the base metal will be leading to the narrow heat affected zone. So the Hz associated properties and the weld metal associate properties are very less if the base metal is clean.

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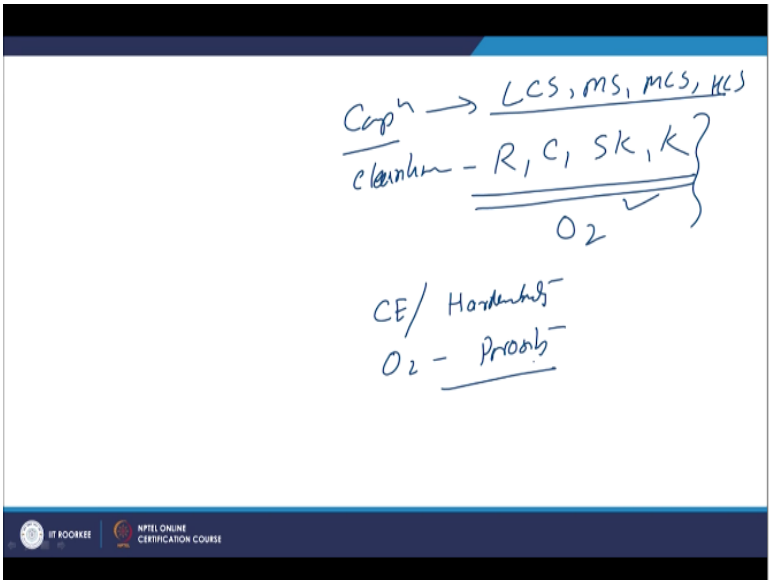

So this is the main aspect as far as the laser and electron beam welding is concerned, **so** but with the steels we have our in terms of the composition, in terms of the cleanliness like we may have the low carbon steel, mild steel, medium carbon steel, high carbon steel likewise rimmed steel, capped steel, semi killed steel or the killed steel. So different compositions, different purity level with regard to the oxygen as far as the cleanliness is concerned.

And therefore we come across the different carbon equivalent due to the different compositions as well as hardenability related issues and since the oxygen concentration is also changing for the different category or different grades of the steels and that is why the porosity related problems will also be changing.

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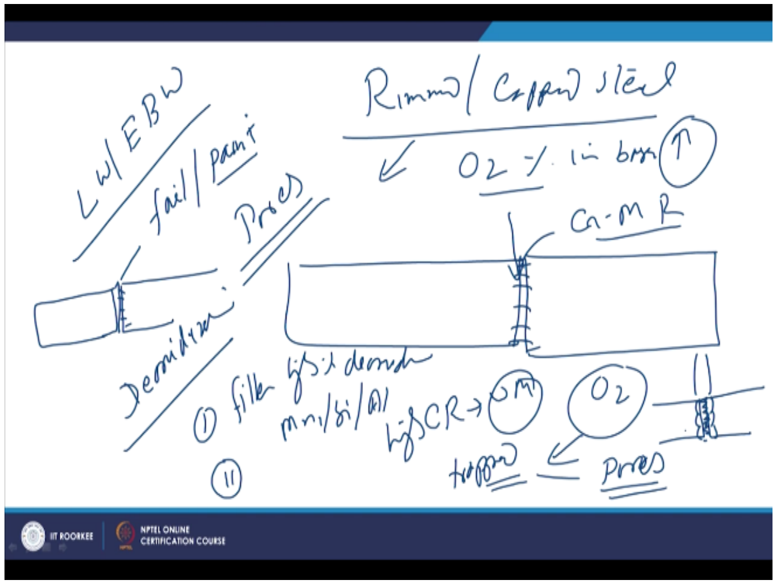

So as far as the laser welding or electron beam welding of the rimmed and capped steels are concerned which are not actually deoxidized for retaking care of the oxygen contents, so the oxygen percentage in the base metal is very high and because of this when the seats or the plates to be welded either of the low carbon, medium carbon, high carbon or mild steel. They will be leading to the removal of the oxygen very violent gas metal reactions will be taking place due to the release of oxygen.

And this under the high cooling rate conditions being experienced by the weld metal this oxygen most of the time gets trapped, so the trapped oxygen eventually appears in form of pores. So the rimmed and capped steels when subjected to the laser or the electron beam welding they imports lots of problems associated with the porosity and it take care of this porosity we certainly need very systematic and proper deoxidation deoxidizer.

So that the dissolved oxygen can be taken care of and for this purpose if you are using filler then the fillers with the high percentage of the deoxidizer can be used so that the when filled is added in form of magnesia, silicon or aluminium in the weld metal it will be able to interact with oxygen and will be able to remove it from the weld metal, another one is that, these deoxidizer if not being fired from outside in form of filler.

Then these can be applied at the faying surfaces in form of these can be applied by placing the deoxidizer in form of foil, in form of paint is applied at the faying surfaces or the thermal spray coating is applied the deoxidizer in form of thermal spray coating is applied at the faying surfaces. So that it is present, the main idea is that at the faying surface we should have the at the interface we should have deoxidizer.

So when the heat source is applied in addition to the base metal this deoxidizer will also be melting and that is how it will be taking care of excess oxygen which is there in dissolved state in the rimmed and the killed steel.

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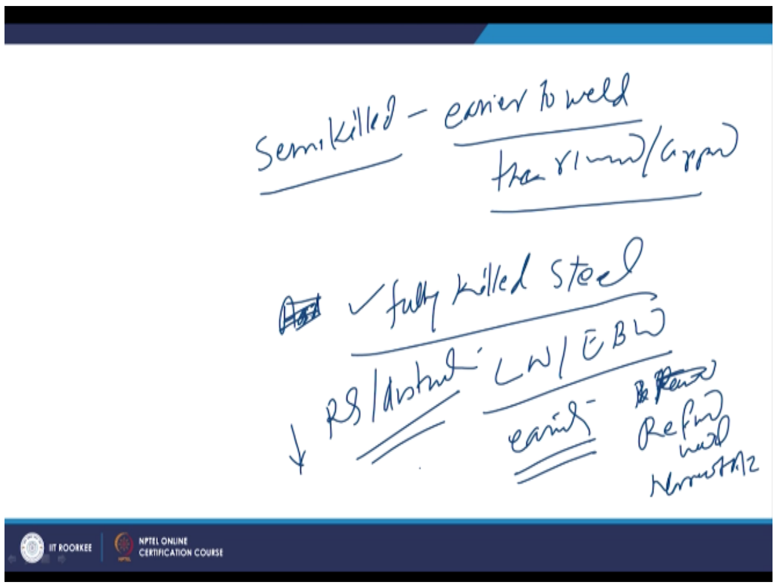

So as far as the semi killed steels are concern these are somewhat easier to weld by the laser and electron beam welding then the rimmed and capped steels. So for these advanced welding processes these advanced welding process like laser and radiation, laser and electron beam processes it will be better to use the fully killed steels. So when the fully killed steels are subjected to the laser welding or electron beam welding.

These are very easily weldable, so automatic laser or electron beam welding processes can be easily applied for the fully killed steels which will be resulting in very fine grain structure very refined weld metal and very narrow Hz and therefore reduced residual stresses related problems reduced distortion tendencies which are other benefits related with the use of the laser and electron beam welding process.

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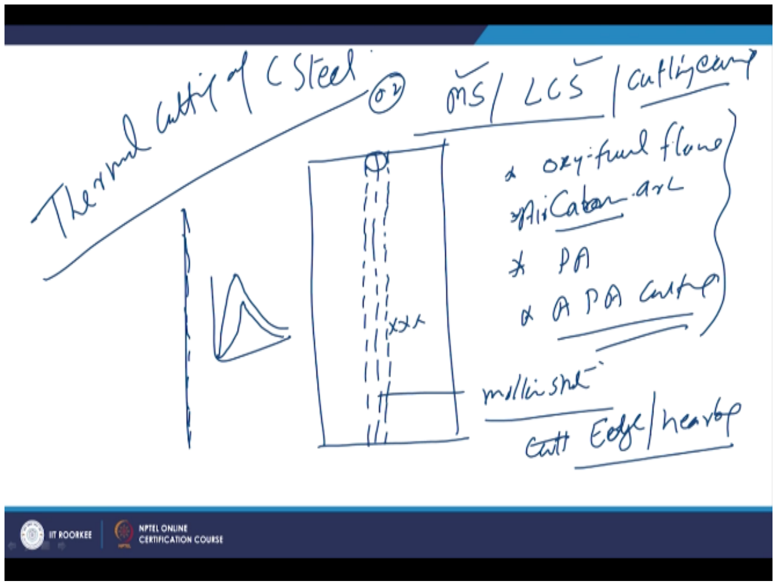

Because this result in very small weld area very little very narrow heat affected zone. Now coming to the thermal cutting of carbon steels, so as far as the mild steel and the low carbon steel is concerned thermal cutting means what like this is a big plate and we want to cut particular size or shape. So we will be applying a suitable source of heat with source of heat may be in form of oxyfuel flame, it may be in form of carbon, air carbon arc, this carbon electrode is used and the compressed air is used for assisting cutting.

Then plasma arc can be used, so here air plasma arc cutting machines they are very effectively used for cutting the thick plates, so whatever is the type of the heat source is being used in all these cases the metal is brought to the handling or oxidation temperature and then oxygen jet is fed so that the oxidation can take place and through exothermic reaction heat is generated and the fusion is facilitated to blow out the molten metal.

And it will be moved along the line where cut is to be made, but in this process since the things are brought to the along the line of the cut the metal is brought to the molten state. So the conditions here are very similar to that building where the melting followed by the certification led to the development of joint, in this case metal is brought to the molten state and it is removed for splits to the jet of aero jet or the high pressure oxygen jet.

In the subsequently whatever left out the metal at the cutting edge is there that will be solidifying at the ages, so the conditions are almost the same except that here the weld metal whatever the fusion metal is there that is blown away from the region where it was applied. So the cut edge the edge which has been cut and the nearby area these will be experiencing the conditions as far as the thermal cycle is concerned similar to that of the world thermal cycle which is like it faster heating the zones which are close to the line of cut.

And then fast cooling, zones which are away from the line of cut they will be heated slowly and they will be cool slowly. So the thermal cycle at a particular location will be similar to that of the welding, so higher heating rate as well as higher cooling rates both will be experienced in the thermal cutting as well and therefore if the steel is of the higher hardenability then it will be problematic from the hardening point of view.

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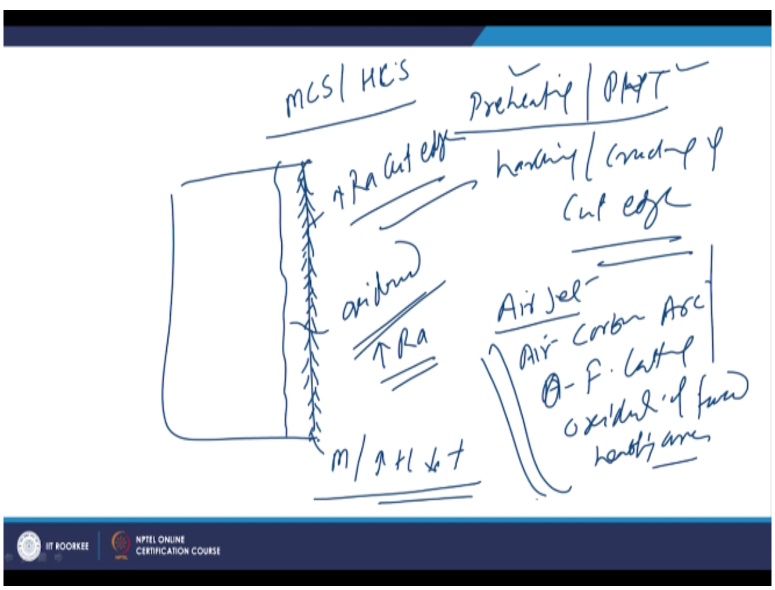

So as far as the mild steel and low carbon steel is concerned there is no hardenability issue and it can be cut easily soon, cutting is easy in case of the mild steel and the low carbon steels but if it is the medium carbon steel or high carbon steel then just like welding we need to take care of proper heating and the post heat treatment. So that unnecessary hardening and cracking of cut age can be reduced h.

If because of the hardenability the cut edge will be experiencing very high cooling rate and this will be experiencing the martensite transformation increase the hardness, reduce the toughness. So because of all these the cut edge will be showing the greater tendency for the embrittlement as well as cracking in order to reduce the tendencies it will appropriate to use the proper preheat and the post heat treatment just like in welding.

So because of all this the cut edge will be showing the greater tendency for the embrittlement as well as tracking so in order to reduce this tendency is it appropriate to use proper period and the post heat treatment just like in welding, so that the such kind of the tendencies can be reduced. There is another possibility like since we are using air jet like in air plasma cutting or in case of the air carbon arc cutting or in the oxyfuel cutting method.

In these cases a lot of oxidation of the metal being used as well as the nearby area takes place, so the zone which is being heated to the high temperature that will be getting oxidized. So this kind of the oxidation will be reducing the smoothness or will be increasing the roughness, at the same time oxidation of the fused metal at the cut edge which will be resolidifying at the cut edge.

This way also will be leading to the increased roughness of the cut edge which has been produced. So we need to reduce the such kind of tendencies for unnecessary turbulent are extremely high oxidation of the cut edges.

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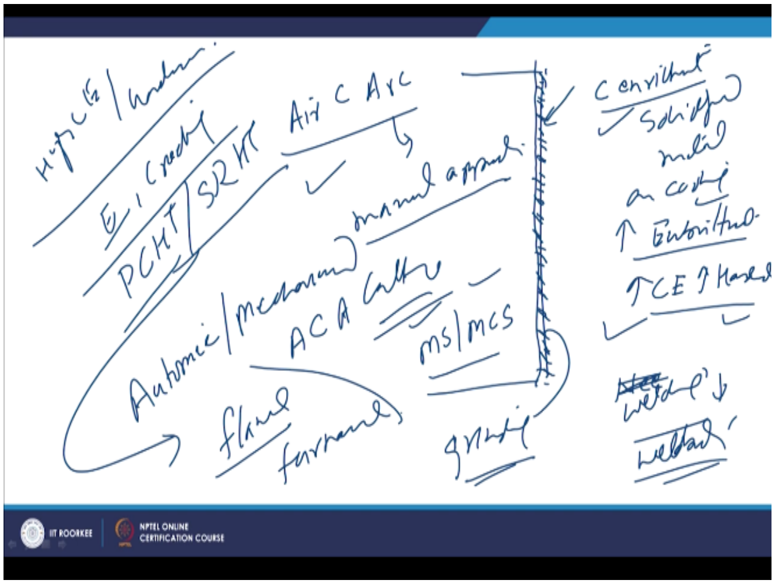

Now we will see there is another aspect this thermal cutting that when the air carbon arc is used for cutting purpose especially in case of the mild steel and medium carbon steels during the air carbon arc cutting the cut edge is contaminated with the carbon and this contamination is primary in form of carbon enrichment. So the carbon enrichment of the solidified metal on cooling leads to the embrittlement.

Because the carbon enrichment of the cut age will be leading to the increase of carbon equivalent which in turn will be increasing the hardenability. So the embrittlement and cracking tendency of the medium and the mild medium carbon steel and the mild steel which is being cut through the air carbon arc using the manual manually approach is manually if air carbon arc cutting is performed of the mild steel.

And the medium carbon steel then enrichment of the carbon at the cut edge will be leading to the increased carbon equivalent increased hardenability, increase the embrittlement tendency and cracking tendency. So if the such kind of the steels needs to be welded, welding is to be performed then high (()) (18:50) or high carbon content at the cut ages will be reducing the weldability.

So that the air carbon cut steel plates must be cleaned by grinding so that this on the carbon in which there from the cut edge can be removed and unnecessary adverse effect on the weldability related to the carbon in which month can be reduced such kind of the issues are not encountered when automatic or mechanized a air carbon Arc cutting is applied in any case if due to the high current and high hardenability.

If the cut edge is experiencing the embrittlement and cracking tendency it is always good to perform the post cutting heat treatment or the stress relieving heat treatment so that the cut edges can be soft and the restless dresses can be relieved and for this heat treatment or either for stress relieving or the post cutting we may use the flame itself or the Furnace so that suitable exposure is given at high temperature to the cutlets induced the favourable properties in the steel.

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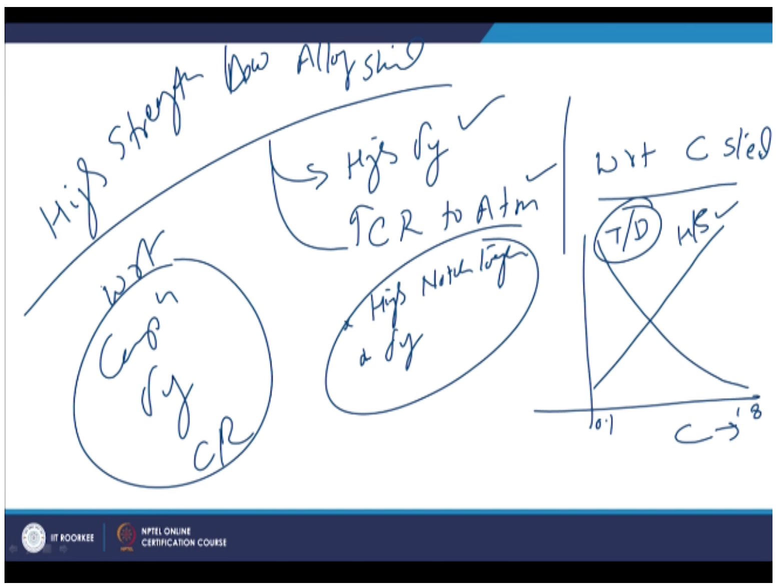

Now we talk about so this is where we complete about the weldability aspects of the carbon steels, now will take up the some introduction aspects of the high strength, low alloy steel. So this classification is primarily based on the, this classification of the steel is based on the mechanical properties where these are designed for high strength. So high strength, low alloy steels. These are design primarily for the high yield strength.

At the same time the composition is also adjusted in such a way that the corrosion resistance to the atmospheric condition is also good. So these are 2 main goals of development the high strength, low alloy steels. So that they have high yield strength and good corrosion resistance to the atmosphere with respect to the simple carbon steels. In simple carbon steels these basically suffer from the property deterioration with the increase of carbon content especially with regard to the toughness and ductility.

So if the carbon content is say is increasing 0.1. 0.1 to 0.8, then will notice that toughness and the ductility will both will be going down while the hardness and strength will be increasing. this is undesirable effect because hardness and strength is increasing but at the cost of the toughness and ductility. So controlling alloying in form of various elements helps to increase the strength without compromising much of the toughness and ductility.

And that helps in developing the steels of the high notch toughness the high yield strength. So these favourable combination of the mechanical properties is realized through the controlled alloying of the steel. So HSLAs differ from the carbon steels with respect to composition as well as the yield strength and the corrosion resistance. So where from these steels get their strengths.

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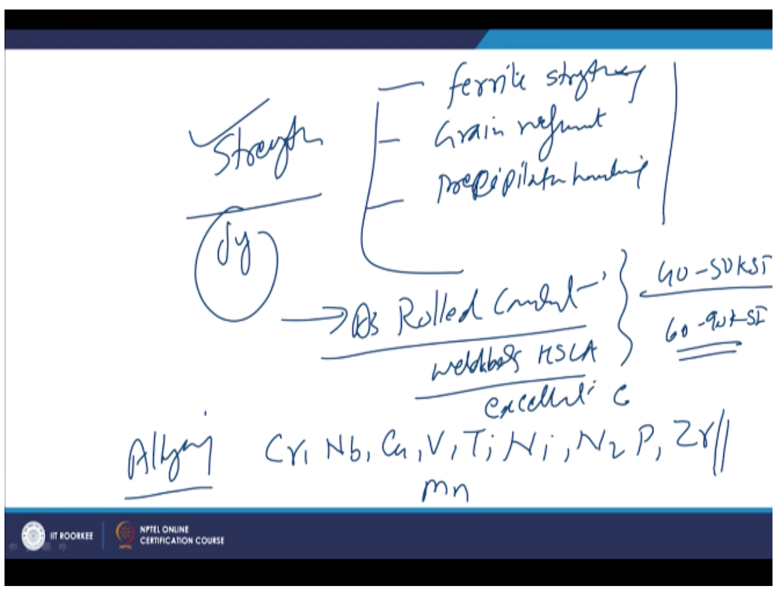

So whenever our the controlled alloying is done using the various elements very wide range of the elements are there which are added in very small quantity this strength, so the strength is enhanced through the various mechanisms like the ferrite is strengthened either through solid solution strengthening. So ferrite strengthening, then the grain refinement, then controlled precipitation, precipitation hardening.

So these are 3 important aspects which will be helping through increase the strength of the at the same time some favourable composition also helps in increasing the corrosion resistance of these steels. these steels are designed to have the highest rank so that these can be directly used in the as rolled conditions. So most of the time these are welded in as rolled conditions and the typical strength which is available with the steel is 40 to 50 KSI for yield strength and like 60 to 90 KSI for ultimate tensile strength of these steels.

And the alloying element concentration is so low that the weldability of the HSLAs is excellent or similar to that of the carbon steel. So the alloying does not deteriorate the weldability despite of giving the improvement in mechanical properties and the good corrosion resistance. So there are a range of the alloying elements which are added in order to realize the strength as well as the corrosion resistance.

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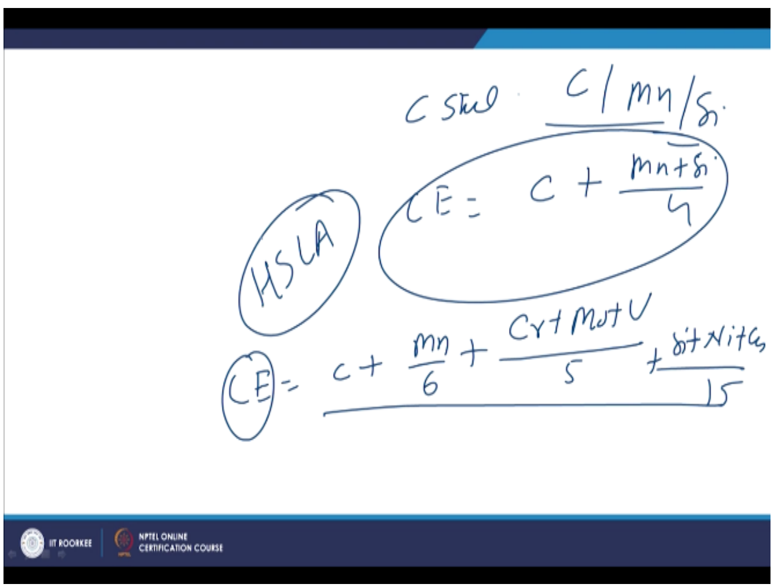

These may be in form of chromium, niobium, copper, vanadium, titanium, nickel, nitrogen, phosphorus, zirconium, manganese, these are some of the elements which are normally added for realizing the specific set of the properties and since the carbon steels primarily had carbon and manganese there and the silicon. These were the 3 elements which are controlled and that is why the carbon equivalent was calculated using C the weight percentage of carbon+Mn+Si/4.

These were the only elements which are considered, but in HSLAs we have very wide range of the alloying elements so accordingly we have to use the different equation for calculating the carbon equivalent like CE=carbon+manganese/6+chromium, molybdenum vanadium/5, then silicon, nickel+copper/15. So these are the most common elements which are added in HSLAs.

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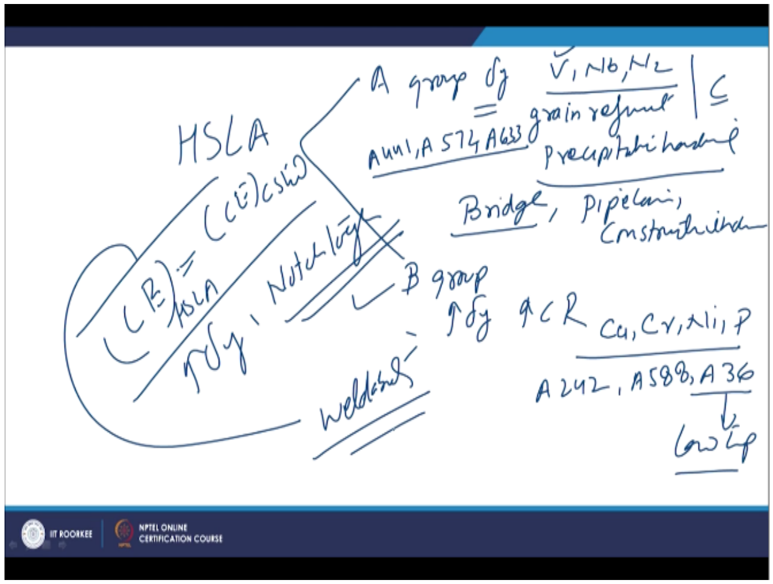

And this equation can be used to calculate the carbon equivalent for HSLAs high strength low alloy steels. Now there are all HSLAs are grouped in three 2 broad categories 1 is like high strength low alloy Steels that 2 broad groups is A group, group A is steels are primarily designed for high yield strength and this is realized with the addition of the vanadium, niobium and/or either singly or in combination or sometimes nitrogen is also added in very controlled way.

These additions in steel helps in grain refinement, so which in turn helps in increasing yield strength to hall-patch relationship as well as these also form very fine very fine precipitates of the vanadium and niobium, so precipitation hardening is also facilitated by the vanadium, niobium, nitrogen in combination with the carbon which is present in the steel. These steels are primarily used for structural applications like construction of bridges, pipe lines in construction industry.

There is a another category or the group of the HSLAs B group, these are designed for both high yield strength as well as high corrosion resistance and this is facilitated through the addition of the copper, chromium, nickel and phosphorus and these steels are used of course for those critical applications where corrosion resistance is critical and typical ah HSLA steels which fall in B group includes like A242, A588 and A36.

This typical steel is used for low temperature applications, on the other hand the typical steels which will be falling in group A include like A441, A572 and A633, if we noticed that CE of most of these carbon CE carbon equivalent of HSLAs CE of HSLA may be almost similar to that of the CE of the carbon steels, but the yield strength will be significantly high, the notch toughness which is measured in terms of the impact resistance of these is steels charpy notch toughness or impact resistance of the steel that is much better than the carbon steels and which is attributed to the presence of these alloying elements.

So for the same CE we get the much better set of the properties as compared to the carbon steels and the weldability is also of the similar type or the better than the carbon steels. So the weldability aspects of the high strength low alloy Steel I will be talking in the next presentations. So I will summarize this presentation, in this presentation basically I have talked about the weldability of the carbon steels with respect to the radiation based processes and also I gave the introduction of the high strength, low alloy steels, thank you for your attention.