

Lecture 52 : Weldability of High Strength Low Alloy Steels

Hello, I welcome you all in this presentation and we are talking about the weldability of the high strength low alloy steels. So, the steels or HSLAs which are designed for high yield strength, they primarily contain the elements like vanadium, titanium, niobium and these act as carbide formers, as well as grain refiners. Since these are very strong carbide formers, so these help in pinning down the grain growth, grain boundary movement and that helps in grain refinement. At the same time whenever these elements are present in steel. So which is a combination of iron plus carbon where in addition of these elements which are having the high affinity to the carbon they form their carbides in form of vanadium carbide or titanium carbide or niobium carbide.

These carbides are very stable. So, they do not decompose easily during the welding under the effect of weld thermal cycle. So, these elements these carbides which are present in the matrix these do not dissolve easily. during due to the weld thermal cycle being experienced at different locations.

So, because of their good thermal stability and resistance for the thermal decomposition at high temperature unless very long exposure at high temperature is given. As a result of this the carbon is consumed by these carbides. So actual carbon content present with the steel is reduced and reduced carbon content in the steel which has not gone into the solution in the austenitic state is not will not be able to contribute the effect on the hardenability. So the effectiveness of the CE due to this effectiveness of the CE is when all these elements go into the solution and homogeneous solid solution of all these elements is formed. But if these elements are forming the carbides and compounds and these are not getting dissolved Then their effect on the carbon equivalent will not be that high.

Since some of the carbon is being consumed by these carbides so their effectiveness will also be reduced. So as compared to the carbon steels HSLAs which are forming these carbides and during the welding not getting decomposed. So, these HSLAs offer better weldability as compared to the carbon steels. So, with regard to the weldability of the HSLAs in general HSLAs offer better weldability than the simple or plain carbon steels. Now if we talk of the typical details related with the weldability of high strength low alloy steels.

Then we need to talk about the 4 different aspects, one is like the kind of preheat which is to be used during the welding of the HSLAs. Then what welding processes we can use and what are the issues related with. Then what kind of the filler metal we can use and what are the options available for welding the different category of the or different types of the high strength low alloy steels. And which type of the post weld heat treatment is needed and what will be the purpose of the same. In general HSLAs offer very good weldability.

and can be welded easily using most of the welding processes. But considering the comparatively high carbon equivalent due to the presence of alloying elements these are it is

always preferred to use suitable preheat. and the low hydrogen practices during the welding. Because whatever weldability whatever hardenability is there due to the presence of alloying elements. So, because of that hardenability efforts are made in order to reduce the unnecessary excessive hardening, embrittlement, cracking tendency. And for that purpose only the HSLAs during the welding of the HSLAs we follow proper preheat and the low hydrogen practices whatever kind of the welding process is used.

So whenever we use a preheat of course for the preheat will be the function of the composition and thickness of the plate of the plates or the section thickness which is to be welded. Whenever we apply preheat, preheat helps to reduce like these are the plates this is the weld centre line. So, the preheating is to be done with minimum up to the distance means from the distance up to which preheating should be done will be equal to the thickness of the plate or 75 mm whichever is larger. So, sufficient width of the plate must be heated in order to have the suitable effect of the preheat. on the weld thermal cycle of the weld metal as well as heat affected zone.

So, the preheating of the region equal to the thickness of the plate or 75 mm or 3 inch whichever is larger that is the distance up from the weld centre line which up to which preheating should be done up to the required temperature. We know that whenever preheating is performed it reduces the rate of heat extraction from the region wherever heat is being applied to the suitable heat source. So, because of the preheat the rate of heat transfer away from the weld centre line to the base metal is reduced and as a result of this our cooling rate is reduced. Reduced cooling rate in the weld metal and the heat affected zone for the carbon equivalents which are typically available with the HSLA steels. The martensitic transformation tendency is reduced, so reduction in cooling rate will be reducing the martensitic transformation tendency which in turn will be decreasing the hardness of the weld metal as well as heat affected zone which has been preheated.

Reduced hardness at the same time it will also reduce the residual stresses being developed in the weld as well as the heat affected zone. So, all these things will be favourable with reference to the reducing cracking sensitivity and cracking tendency of the weld metal. So, the preheating will be helpful in controlling the cracking tendency, controlling the embrittlement. At the same time since these steels if they are subjected to inappropriate cooling rate leading to the martensitic transformation, high hardness, higher tensile residual stresses then in presence of hydrogen these can also lead to the hydrogen assisted cracking therefore suitable practices like low hydrogen control, consumables, processes, proper cleaning, proper preparation and all that whichever is needed, whatever is needed to have the lower hydrogen concentration in the weld metal is used. So there has to be a minimum preheat temperature should be used so that it is able to reduce the cooling rate and it is able to reduce the cracking tendency of the weld as well as heat affected zone. And this cracking tendency will be more critical or will be more severe when the weld joint means the ends are fixed and the joints are being made here.

So, the heat expansion during the heating and subsequent contraction can be more problematic with regard to the cracking tendency. So, as I have said there are two broad groups of the HSLAs. The group B is primarily for the high yield strength as well as corrosion resistance and group A is mainly for high yield strength steels. Like when the plates of the different thicknesses are welded of say up to 0.

75 inch. So, the plate thickness in inch then 0.75 to 1.5 inch then 1.5 to 2.5 inch and greater than 2.

5 inch. So, when the plates of the different thicknesses are to be welded of the group A steel say So, there are different grades of the group B steels like A242 steel, A441 steel, A572 steel, A588 and A633 steels. So, all these steels when they are used or they need to be welded in different thicknesses then the kind of preheat which is used will be different like say the preheat to be used in Fahrenheit. for up to 0.75 mm thickness the temperature, preheat temperature especially for those conditions those regions where temperature is very low. So, the minimum the base plate temperature, preheat temperature and inter pass temperature has to be like 32.

When that thickness is in the range of 0.75 to 1.5 mm then it is 50. When the thickness is in the range of 1.

5 to 2.5 then it is 150 and for greater thickness, thickness greater than the point 2.5 inch it is 225 Fahrenheit. On the other hand the HSLAs of the group A which are primarily designed for high yield strength they need much higher temperature like the typical steel of the group A is A572. And the kind of the temperature which is to be used for preheat is 50 degree Fahrenheit up to 0.

75 then 0.75 to 1.5 inch it is 150 and then for next 1.5 to 2.5 inch thickness it is 225 and For grid thickness is greater than 2.5 inch it is 300 Fahrenheit. So the group A steels need higher, there are many for the sub classifications in each category of the steels.

So this is a one bigger group, group A and group B type of the steels, group A steels need higher preheat as compared to that of the group B steels. Now coming to the welding processes like all, so next is the welding process, all common welding processes like shielded metal arc welding, gas metal arc welding, gas tungsten arc welding, submerged arc welding, plasma arc welding. All these can be effectively used for welding of the HSLAs. However, as per the composition and the thickness we need proper preheat as well as the suitable filler composition is also to be selected and as per the requirement PWHT is given depending upon the fabrication conditions and the cracking sensitivity of the metal.

If we just have a look like the typical microstructures of the carbon steel and high strength alloy steels. Carbon steels primarily contain carbon while the manganese, silicon, phosphorus and sulphur are the residual elements. These will primarily be containing the

alpha ferrite and pearlite which is a mixture of the ferrite and cementite. So all this white phases are of the ferrite and the dark zones are representing to the pearlite where pearlite which is the mixture of the alpha ferrite and Fe₃C iron carbide that is the cementite. This structure is in general coarse.

offers the lower yield strength lower hardness as compared to the HSLAs. Structure we can see is very fine as compared to the carbon steel on the other side it contains the ferrite. So, pearlite may be containing the fine bainite or martensite also depending upon the kind of the thermal and mechanical history of the steels. are the common phases which are found. The structure is in general finer for the HSLAs as compared to that of the carbon steel.

And what this table shows that the kind of the minimum preheat which is to be used. As I said this is the group A HSLAs for different thicknesses we need the different magnitude of the preheat ranging from 32 to 25 for group B steels and for group A steel we have like 572 and 633. These are the different sub grades of because we have 572 here and 572 here as well. So grade 42 and grade 50 it is in group A and another group B and this is another 572 of grade 60 and 65. So, the different grades of the HSLAs will be requiring the different magnitude of the preheat.

So, in any case increase in thickness of the plate we need to increase the kind of preheat which is to be used. So, the minimum preheat temperature is increased with the increase of thickness as well as with the change of alloy composition also the preheat is affected. Now we were talking about the welding processes which are used for the welding of the HSLAs. So, as I have said most of these welding processes can be effectively used using the suitable combinations of the preheat as well as the filler metal. so that the required the tensile strength and the corrosion resistant properties can be realized.

So, these processes offer the heat input, net heat input in a range which is acceptable and does not affect the weld metal as well as HAZ properties appreciably. On the other hand there are certain processes like electro slag welding, electro gas welding or submerged arc welding performed using extremely high heat input. So in those cases we get very coarse grain structure. in HAZ as well as in the weld metal. So, because of the coarse grained structure as well as the formation of the unfavourable phases due to the low cooling rate being experienced like in electro slag welding.

the weld is cooled because of the very high heat input weld metal is cooled very slowly as well as the heat affected zone is also cooled very slowly. So, we get the very coarse pearlitic structure and such kind of the structures reduce the notch toughness. of the HSLAs. So for most of the normal applications all common welding processes can be used because the notch toughness, the yield strength both are very good which can be realized using most of the common welding processes but if the notch toughness is a criteria Then we need to be very careful with regard to the H net because heat input affects the cooling rate and that in turn affects the grain structure and which can lead to the deterioration in the notch

toughness. So all those critical applications of HSLAs.

where notch toughness is critical there we must see like the kind of preheat being used, the welding process being used. and the kind of the filler metal which will be used. Because these are the things that will be governing the end microstructure in the weld metal as well as heat affected zone. Preheating affects the cooling rate, welding process affects the heat input and so again the cooling rate and the filler metal affects the composition and which in turn determines the kind of phases which will be up. developed for a given set of the cooling conditions.

So, we should consider the preheat, the welding process as well as the filler metal composition. If the notch toughness of the HSLA weld joints is crucial otherwise the kind of the notch toughness which is offered by these processes and most of the common welding processes is very acceptable for general applications. Apart from these processes whatever process we adopt we must follow the practices for low hydrogen practices. We must follow the low hydrogen practices, so whether it is the preparation or consumable or the process or post weld heat treatment. Whatever is needed to control the hydrogen in the weld as well as heat affected zone all those principles must be applied.

So that the given weld joint of the HSLA when it is developed using a given set of the process is able to. is able to develop the weld joint with the required toughness. Now we will see that since the electro slag and electro gas and SAW which is performed using very high heat input we do not require any preheat. Because these processes are of the so high heat input that cooling rate is low enough in order to facilitate the formation of the softer phases and sometimes even the phases are so soft and so coarse that they deteriorate the notch toughness and the mechanical properties of the metal. Notch toughness can be one issue especially when the very high heat input and the low cooling rates are used that in turn will be leading to the deterioration in the notch toughness of the weld joint.

So, for that purpose we need to control the heat input properly. Now as I have said the preheat and the post weld heat treatment cycles. in case of the resistance welding processes. So with regard to the resistance welding processes because in most of these processes the rate of the heating, heating rate is very high and after the heating the force is applied followed by the cooling at a very high rate. So, the heating rate and the cooling rates both are high when the resistance welding processes are used for welding of the HSLAs.

Say resistance welding process like the spot welding or the seam welding when it is these are used. So, in that case since these are of the high yield strength processes. And there the resistance for the flow of current is almost same as that of the carbon steels that is why the kind of the current setting and the welding current time. These values are almost same as that for the carbon steels, but if we talk of the current the pressure, the forging pressure or the pressure which is to be used during the spot welding or the seam welding. So, the pressure for the HSLAs is used much higher than what is used in the carbon steels and the

reason for this is that high strength steel since HSLAs are of the high yield strength.

So, in order to facilitate the proper upsetting and forging action during the welding cycle the pressure must be higher than what is used in case of the carbon steels. So, the current and the time settings for this resistance spot welding of the HSLEs are same as that of the carbon steels but the pressure requirement or the load required for For realizing the upsetting and the forging action during the welding these pressure or the forging upsetting force must be high, must be higher than what is used in the case of the carbon steel. So that required upsetting and forging action can be realized for developing the sound weld joint. Since the heating and cooling rates are very high, so in order to avoid the possibility of the excessive hardening and embrittlement.

and a related cracking tendency. If you want to reduce these because the HSLAs have the high carbon equivalent and since the cooling rate and the heating rate and cooling rates are also high, so these will be sensitive for hardening, embrittlement and cracking. So in order to reduce the hardening, cracking and embrittlement tendencies. Like typical preheating and the post weld heat treatment cycles can be incorporated during the resistance welding processes, so that the cooling rates. can be reduced and the formation of the softer phases can be facilitated in order to avoid the unnecessary hardening or the embrittlement and cracking tendency of the resistance spot weld joints of the HSLEs.

As far as the filler is concerned. filler metal. Some of the welding processes are of the non-consumable welding processes and there are few consumable welding processes. So, the line or the criteria for selection of the filler metal for HSLA is similar to that of the carbon steels like for matching strength we choose the matching filler but if we require some specific property in the weld metal then different filler is chosen in such a way that it not only provides the the required set of mechanical properties but response to the heat treatment is also same as that of the base metal. So, that uniformity in the weld as well as weld metal as well as the base metal properties can be realized after the post weld heat treatment. And at the same time like I have said that if the notch toughness requirement is crucial for the weld metal then we may choose the high notch toughness requirement. weld metal fillers, the fillers which will provide the higher notch toughness.

So like ASS can be used for welding of the HSLAs provided other strength requirements like yield strength requirements are satisfied because this will provide very good the resistance to the notch toughness. Now we will see there is like the different the fillers and the consumables which are used for welding of the high strength low alloy steels which are used for joining of the various structural components. So, the different grades of the HSLAs. When they are welded using the shielded metal arc welding these are the set of the electrodes, most of these are the low hydrogen electrodes of the 7000 series. And another category or the group of the HSLAs like 572 and A633, these grids are welded using these 3 types of the electrodes of the SMAW for SMAW process.

Likewise for submerged arc welding there is a combination of the filler as well as the fluxes which will be able to offer the required set of the properties. These are the typical fillers for the gas metal arc welding and the fillers which are used for the flux code arc welding process are given this table, now these are the typical electrodes which are the filler metals which are used for the shielded metal arc welding process for the different grades of the HSLAs. And these are the different kind of the electrodes which can be used for the welding of the HSLAs by the SMAW process and these are the typical elements which are present in the different grades of the steels. Now we will see the kind of the preheat which is a post heat treatment which is to be used for the welding. Normally in structural welding so PWHT post weld heat treatment structural welding of HSLAs does not require.

require PWHT, post weld heatment is normally not required for most of the structural welding of the high strength low alloy steel weld joints. But we know that whenever the steels are welded these invariably develop the residual stresses. So presence of the residual stresses will be increasing the tendency for distortion. especially after machining. So if you want the dimensional stability of the HSLA weld joints after the machining or during the machining there is no dimensional change or the shape change then after the welding we must perform the machining.

And this is primary goal of the performing this PWHT is to relieve the residual stresses. So the residual stress relieving is the main target so that during the machining there is no distortion as well as at the same time the relieving the residual stresses also helps in reducing the stress corrosion cracking tendency. Because, if the weld joint is used in the corrosion environment and if the tensile residual stresses are present in the weld metal or in the heat affected zone then it will be sensitive for the stress corrosion cracking. So, in order to avoid such kind of the possibilities post weld heat treatment is given to the So, main purpose of this is to relieve the residual stresses so that these benefits can be availed. For the critical components PWHT must be established so that we can ensure welding procedure specifications should be established, it should be tested and then we should follow those the procedural steps very meticulously and very closely so that the required performance of the weld joint can be realized.

So now I will summarize this presentation, in this presentation basically I have talked about the weldability of the high strength low alloy steels wherein I have talked about the kind of the preheating, temperatures to be used, what are the welding processes and its effect on the properties of the HSLA weld joints, how the fillers are selected and what kind of the post weld heat treatments are given. As far as the post weld heat treatment is concerned there is one typical The temperature range which is used like the different the steels and the kind of the post weld heat treatment temperatures which are to be used so that residual stresses can be released. Thank you for your attention.