Lecture 56: Weldability of Cr-Mo Steel - II

Hello I welcome you all in this presentation and we are talking about the weldability of the chromium molybdenum steels. And these are the heat resistant steels which are used for fabricating the components used in the thermal power plants like say in temperature range of normally 500 to 650 degree centigrade. and the petrochemical industry where at the high temperature as well as corrosion resistance applications involve use of the chromium molybdenum steels. So in the last lecture I have talked about the general properties of the chromium molybdenum steels the different chemical compositions of the chromium molybdenum steels. and the way by which chromium molybdenum steel weld joints responds to the heat of the welding. Now we will try to see the way by which the kind of the welding metallurgy involved in involved in welding of the chromium molybdenum steels.

We know that the chromium in these steels can range from 0.5 to 9% while molybdenum usually 0.5 to 1% while carbon is generally less than 0.2%.

And in some cases only it may be like 0.35% for high carbon cases. So, if we see as a whole the chromium molybdenum concentration in these steels apart from the carbon. Due to the higher weight percentages of these elements in these steels the carbon equivalent of these steels is found to be very high maybe greater than 0.5 and because of this it offers very high hardenability.

And high hardenability means whatever portion of the steel which is being heated during the welding and getting austenitized like austenite is formed then this austenite will tend to form the martensite and since if the carbon content in this steel is high like 0.2 And due to the higher chromium and molybdenum concentration it leads to the formation of the high hardness martensite. So, one of the issues related to the formation of the high hardness martensite is the embrittlement of weld as well as heat affected zone and because of this embrittlement there will be tendency for cracking. At the same time development of the residual tensile stresses during the welding of these steels also cannot be overruled, so there will always be presence of some residual stresses As well as if the hydrogen is involved or hydrogen is enriched in the weld as well as heat affected zone due to the poor control over the conditions during the welding leading to the enrichment of the hydrogen in the weld. As well as the heat affected zone then the presence of both these sometimes promote the promotes the hydrogen induced cracking or hydrogen assisted cracking.

So, these are the two aspects one is the embrittlement of the weld and heat affected zone leading to the cracking and another one is the hydrogen assisted or hydrogen induced cracking due to the presence of the residual stresses as well as in case when the hydrogen is present in the welding environment. Third and unique kind of the aspect which is observed related with this type of the welding is that the creep embrittlement. This is basically associated with the creep crack formation, this is also known as type 4 cracking. And this is commonly observed in the heat affected zone of the chromium molybdenum steel weld joints. So, about this also we will be talking that what are the factors that lead to the creep So, the first thing is that in order to avoid the embrittlement of the chromium molybdenum steel welds in the weld metal and the heat affected zone the best way is to perform the post weld heat treatment.

So, this will not just be relieving the residual stresses, but it will be increasing the toughness of the weld joints. So, we will be talking about the conditions which are to be used for the post weld heat treatment, so that the toughness can be enhanced. However, the post weld heat treatment in general will be reducing the yield strength of the weldment. Then there is another aspect that in order to control the embrittlement due to the high hardness martensite formation we may use suitable preheat. So, the preheating helps to reduce the cooling rate and which in turn will also be helping in reducing the residual stress formation, reducing the hardness of the martensite which will be formed.

or it will be helping in also easy escaping of the hydrogen if it was there in the weld as well as heat affected zone. So, the delayed cracking and cold cracking tendency is also reduced, we will be talking about the kind of preheat temperatures to be used for. avoiding the embrittlement as well as avoiding the delayed cracking related tendency. And if the low hydrogen welding procedure is adopted then certainly the amount of preheat to be used in order to control the hydrogen induced cracking that will be reduced. So, for that purpose we normally prefer to go for the low carbon welding.

filler metals. So, that whatever weld metal is formed that is of the lower yield strength and of the lower hardness as well as it develops the lower residual stresses. So, which in turn will be helping in to reduce the hydrogen induced cracking due to the residual stress formation. As far as the filler metal is concerned the weld metal composition and accordingly the welding metallurgy to a great extent is influenced by the composition of the weld metal. So, we know that since the chromium, molybdenum and carbon content in the base metal is high.

low carbon fillers. But low carbon fillers will be leading to the reduction in the yield strength of the weldment. And if this is acceptable from the service point of view then we will prefer to use the low carbon fillers while the chromium and molybdenum percentage in the fillers or the electrodes may be same as that of the weld. base metal but we will be trying to use the low carbon filler metal if it is acceptable. Filler metal composition directly affects the properties of the weld metal and more specifically the carbon content in the filler or carbon content present in the weld metal has a direct effect on the properties of the metal.

weld metal that is what we will try to see here from this simple diagram what it shows like carbon content is 0.04, 0.08, 0.12 and say 0.16 this is weight % of the carbon in increasing amount.

In the Y axis I will say this side we have the strength of the weldment increasing from So, this is the minimum level 55 KSI so the tensile strength KSI in KSI unit say here it is 75 somewhere here 85 then 100 then 130 say this is 65. On the other hand this is another axis where we are showing the elongation. Elongation say changing from like say 10, 20, 30 this is the percentage elongation showing the ductility of the steel weld joints. So we will now try to see that how does the How does the tensile strength and elongation of the 2.25 chromium and 1 molybdenum steel weldments will be this is the base metal how its properties will be changing as a function of carbon content when the properties are tested in as welded condition or in stress relieved condition.

So, we will try to see both the variations, so in the one case when the properties of the weldment of the point 2.25 chromium and 1 molybdenum steel weldment is tested the kind of variation that we go property variation is like this. So, here the tensile strength of the weldment as a function of the carbon content. on the this is the weld metal properties. On the other hand when we perform the stress relieving treatment say exposure of the weldment at 1300 Fahrenheit for 1 hour per inch thickness then the way by which the property variation takes place is basically the tensile strength is reduced and what we get here we get the reduction huge reduction in the property.

So, this is stress relieved and the tensile strength of the weld metal in a stress relieved condition as a function of the carbon content. So, of course there is increase in Now tensile strength with the increase of carbon content but there is a huge drop in the tensile strength with the stress relieving heat treatment at say 1300 Fahrenheit for 1 hour exposure per unit in section thickness. On the other hand ductility also comes down hugely with the reduction of with the increase of the carbon content and so what we will see here like the ductility drops to the 5%. This is what is the case in the as welded condition and when we check the same in the When we check the same in case of stress relieved condition then there is a marginal improvement in the ductility of metal. So, stress relieved weld metal shows the higher percentage of ductility for a same carbon content.

While there is a significant drop in the yield in the tensile strength of the weld metal with the increase of carbon content tensile strength is increasing while the stress relieving treatment is reducing the tensile strength significantly. So, that is what we will see in this diagram this also this is the same diagram showing the variation. So, in the tensile strength and ductility as a function of the carbon content for 2.25 chromium 1 molybdenum steel in as welded condition as well as in stress lift condition at 1300 Fahrenheit for 1 hour per section thickness. So, what it shows there is significant increase in the tensile strength in as welded condition but the tensile strength in stress relief condition is dropped significantly.

So, more significant drop in the tensile strength takes place as compared to the kind of benefit that we get in terms of the ductility. So, this is the kind of improvement in ductility which is observed with the stress relieving treatment. Whether it is in stress relieved condition or in as welded condition with the increase of carbon content we are getting increase in tensile strength and the reduction in the elongation or reduction in the ductility of the weldment. Now we will be talking about the creep embrittlement basically it is attributed to the precipitation of residual elements. at prior austenite grain boundaries in the heat affected zone.

So at the grain boundaries some of the undesirable phases precipitates and form the intermetallic compounds and the phases which at high temperature exposure on high temperature exposure like say this temperature is around 700 Fahrenheit to 1100 Fahrenheit. So, exposure in this temperature range leads to the precipitation of the residual elements at the prior austenite grain boundaries and this precipitation weakens the material, lowers the ductility and increases the embrittlement of the chromium molybdenum steels especially in the heat affected zone. So prolonged exposure leads to the cracking in the heat affected zone due to the creep embrittlement and this kind of the embrittlement is attributed to the means is affected by the composition as well as the heat treatment condition of the plates which are being welded. Normally this problem is more severe when the weld joint is used in as welded condition and some of the like normalizing and tempering treatments helps to reduce this kind of embrittlement tendency. Similarly, there are few compositions of the chromium molybdenum steels with the addition of tungsten and vanadium.

They also help in reducing the creep embrittlement tendency of the chromium molybdenum steel weld joints. Since these steels are normally of the high strengths like 100 to 150 KSI, so because of the high yield strength of these steels their weld joints are less tolerant to the weld discontinuities because these easily provide the high stress concentration to promote the crack growth rate and premature failure. So, stress notches all stress raisers. So, the failure of the weldments of the chromium molybdenum steels of high yield strength is significantly promoted by discontinuities, notches and all stress stressors in whatever form they are there like sharp change in cross section or very high stress concentration at the toe of the weld. So, all these will be promoting the crack nucleation as well as their growth if these discontinuities are present.

Weld joint design for chromium molybdenum steel, this design must ensure that there are no stress raisers, stress concentration is minimized as well as there is no sharp change no sharp change in cross section at the toe of the weld or in the cross section of the component or there are minimized the weld discontinuities. weld discontinuities are minimized. Because these kind of the weld joints are less tolerant to the discontinuities and the stress resers and therefore we need to select the such kind of the weld joint which will be reducing the tendency for all these stress resers. So, normally for high strength weld joint butt joint is used and if the weld joint is there in the low stress areas then only the welds are used. So the one very simple thing is that we need to make the efforts to use the groove weld joint as much as possible so that the unnecessary stress results in high strength zone, high stress areas of the chromium molybdenum steel weld joints can be And if the weld joints are falling in the low stress areas then maybe we can use the fillet weld joints also.

So that was about the kind of the joint design to be used. Then there is the kind of the preheat which is needed for welding of the chromium molybdenum steels. You know whenever we apply preheat, preheating of the plate or preheating of the base metal or then interpass temperature whatever preheat is there the same is the interpass temperature is used. Whenever preheat is applied it will be lowering down the temperature. cooling rate of weld as well as the heat affected zone this is one thing.

At the same time it will be increasing the peak temperature being experienced by a particular location in vicinity of the the fusion boundary. So, the heat affected zone will be experiencing the higher peak temperature as well as the width of the HAZ which is formed that increases with the increase of preheat. So, these are some of the aspects which may be favourably used for example the reduced cooling rate. will be giving more time for diffusion of the hydrogen from the weld as well as heat affected zone. So, that the excess hydrogen can be released can escape out and the second is the martensite hardness is also reduced due to the formation of some of the soft phases because the cooling rate So, these are the two very positive sides and may be residual stresses are also reduced due to the reduction in the kind of cooling rate which is being used.

So, these factors in combination help in reducing the cracking tendency, help in reducing the embrittlement. of the chromium molybdenum steel weld joint. So, it is important to use the suitable preheat, so that the softer phases can be formed, hydrogen can diffuse out and the low carbon martensite of the lower hardness is formed residual stresses are relieved. So, these factors will be helping in to reduce the embrittlement of the weld as well as heat affected zone as well as it will also be reducing the hydrogen induced cracking tendency. So, the kind of preheat to be used is directly found a function of the thickness and composition.

So, these are the 2 main factors that affect the magnitude of the preheat thickness and At the same time the preheat temperature is also affected by the welding procedure. If we are using the low hydrogen procedures then the lower preheat temperature can be used. If we are using the filler in such a way that the weld metal will be softer will be of lower yield strength will be having the greater absorption to the hydrogen. Then the preheat temperature requirement will also be decreased, so as an example if we We know that the chromium in these steels can vary from 0.5 to 9% as well as molybdenum can vary from 0.

5 to 1%. So say for an example the 0.5% chromium, 0.5% molybdenum steel. needs the preheat of the 100 degree Fahrenheit if the thickness is less than 0.5 inch. But the same the preheat is will be the 300 if the thickness is greater than 1 inch of the section to be welded.

Likewise if you are talking of the 9 chromium and 1 molybdenum. higher chromium and higher molybdenum percentage then this preheat can be 400 Fahrenheit for thickness less than 0.5 inch and it can be there of the 500 Fahrenheit if the thickness is greater than 0.5. So, it will depend the kind of preheat temperature to be used will be significantly influenced by the kind of the composition, the heat treatment.

At the same time the lower preheat temperature values can be used using the low hydrogen procedures. or when the low yield strength fillers are used like AISI310 or AISI309. These are the austenitic fillers which will have the greater absorption to the hydrogen as well as these will be offering the lower yield strength. So, lower residual stresses will be developed and these factors in combination will be favourable from the welding means from the preheat point of view because even the lower preheats will be suitable to develop the weld joints. So this is what we can see here this list this table shows the kind of preheat temperatures to be used when welding the chromium molybdenum steels using the low hydrogen covered electrodes.

say 0.5 chromium and 0.5 molybdenum is 100 Fahrenheit up to 0.5 inch thickness 100 degree Fahrenheit. While for higher chromium like 0.5 to 5, 7 and 9 chromium this preheat temperature is 2.

400 degree Fahrenheit. So, for higher the chromium and molybdenum concentration greater will be the preheat requirements. Likewise higher the thickness greater will be the kind of preheat temperature requirements. So, 400 for up to 0.5 thickness and over 1 mm it is 500 degree Fahrenheit. So, because increasing the chromium and molybdenum content will be increasing the carbon equivalent which in turn will be increasing the hardenability, so in order to deal with the increased hardenability we need greater preheat temperature, so that cooling rates can be accordingly reduced in order to avoid the embrittlement of the chromium molybdenum steel weld joints.

Now I will summarize this presentation. In this presentation basically I have talked about the welding metallurgy of the chromium molybdenum steels and the way by which the preheat temperatures will be affecting the various aspects related to the welding of the chromium molybdenum steels. Thank you for your attention.