Weldability of Metals
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Lecture-29
Weldability of Cr-Mo Steels-II

Hello, I welcome you all in this presentation related with the subject of weldability of metals and we are talking about the weldability of the chromium molybdenum steels. And these are the heat resistance steels which are used for fabricating the components used in the thermal power plants like say in temperature in of normally 500 to 650 degree centigrade and the petrochemical industry where at the high temperature as well as the corrosion resistance applications involving 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 response to the heat of the welding.

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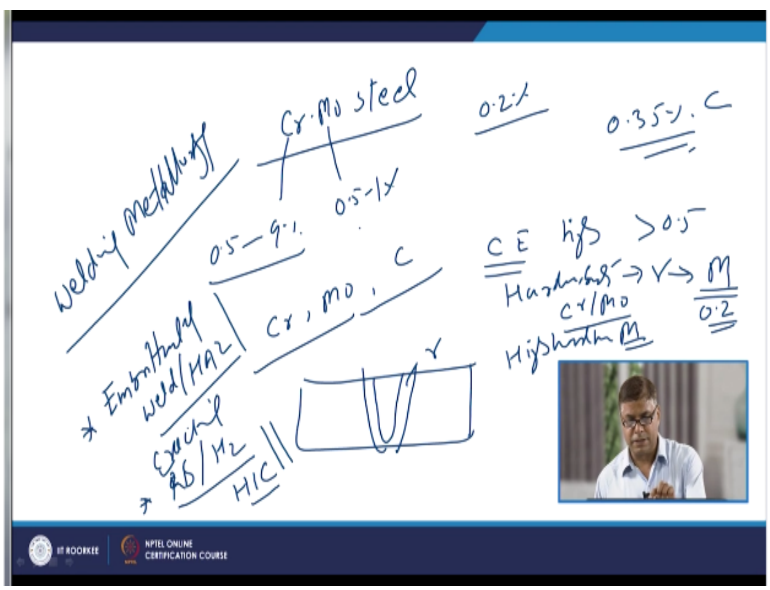

Now we will try to see the way by which the kind of the welding metrology involved in welding of the metrology involved in welding of the chromium molybdenum steels. We know that the chromium in these steels can range from 0.5 to 9% while molybdenum usually 0.5 to 1% while carbon is generally less than 0.2% and in some cases only it maybe 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 % 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 austenitised like austenite is formed.

Then is austenite will tend to form the martensite and since the if the carbon content in these steel is 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 with 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 overrule. So, there will always be presence of some residual 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 hydrogen in the weld as well as the heat affected zone.

Then the presence of both these sometimes promotes the hydrogen induced cracking or hydrogen assisted cracking. So, these are the 2 aspects 1 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.

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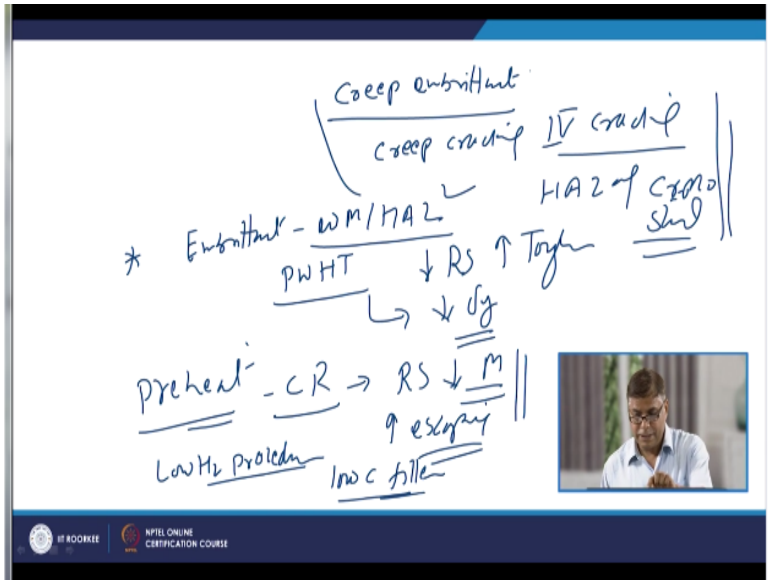

Hard and unique kind of the aspect which is observed related with this type of the welding is at the creep embrittlement. This is basically associated with the creep crack formation this is also known as a type 4 cracking and this is commonly observed in the heat affected zone of the chromium molybdenum steel weld joints. So, about this also we will be trying to will be talking that what are the factors that lead to the creep embrittlement.

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 reliving the residual stresses but it will be increasing the toughness of the weld joints. So, 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 weldments. Then there is another aspect that in order to control the embrittlement due to the high hardness martensite formations we may use suitable preheat. So, the preheating helps to reduce the cooling rate and which in turn will also be helping 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 cool cracking tendency is also reduced will be talking about the kind 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 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 into reduce the will be helping into reduce the hydrogen induced cracking due to the residual stress formation.

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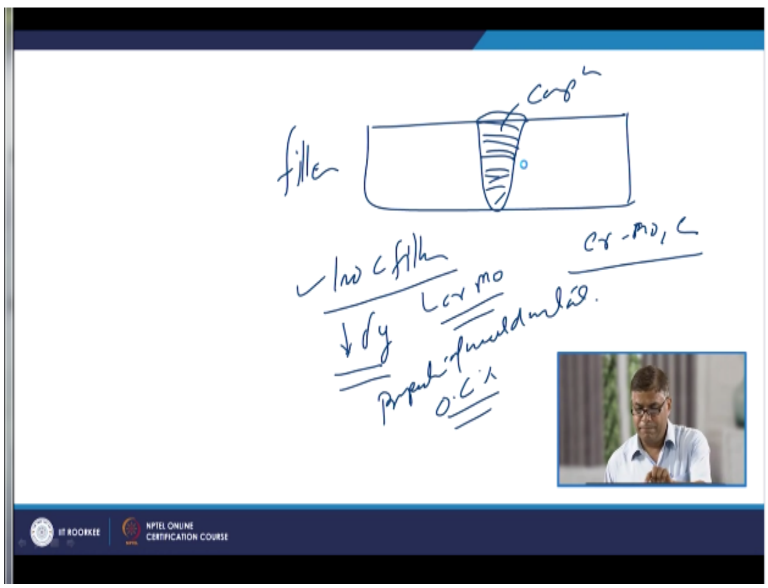

As for as the filler metal is concern the weld metal composition and accordingly the welding metrology to a great extent is influenced by the composition of the weld metal so, we know that since the chromium molybdenum and carbon content in the base metal is high, so we will prefer to use the low carbon 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 maybe same as that of the 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 as a direct effect on the properties of the weld metal.

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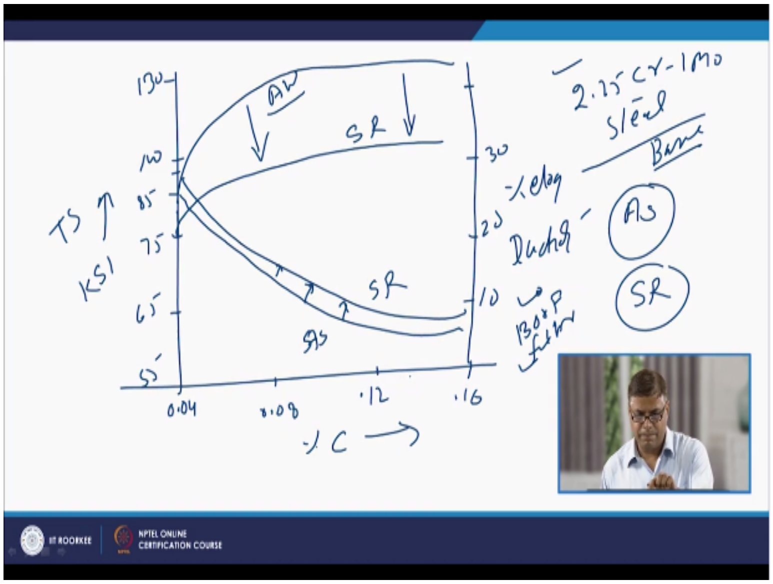

That is what we will try to see here from the simple diagram what it shows like carbon content is 0.04, 0.08 0.12 and say 0.16, this is weight percent of the carbon in increasing amount. In the y axis I will say this side we have the strength of the weldment increasing from say this is the minimum level 55KSI. So, the tensile strength KSI in case a 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 say changing from like say 10, 20, 30 this percentage elongation showing the ductility of the steel weld joints. So, we will now try to see that how does tensile strength and elongation of the 2.25 chromium and 1, molybdenum steel weldments will be this is the base metal how it is properties will be changing.

As a function of carbon content when the properties are tested in as welded condition or in stress relived condition. So, we will try to see both the variations, so in the 1 case when the properties of the weldment of the 2.25 chromium molybdenum 1 and 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 reliving 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 properties.

So, this is stress relieved and the tensile strength of the weld metal in stress relived condition as a function of the carbon content. So, of course there is a increase in tensile strength with increase of carbon content but there is a huge drop in the tensile strength with the stress reliving heat treatment at say 1300 Fahrenheit for 1 hour exposure per unit inch section thickness.

On the other hand ductility also come down hugely with the increase of the carbon content. And so what 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 when we check the same in the in case of stress relived condition and there is a marginal improvement in the ductility of metals.

So stress relived weld metal shows the higher percentage of ductility for a same carbon content while there is a significant drop in the yield and that is tensile strength of the weld metal with increase of carbon content tensile strength is increasing while the stress reliving treatment is reducing the tensile strength significantly.

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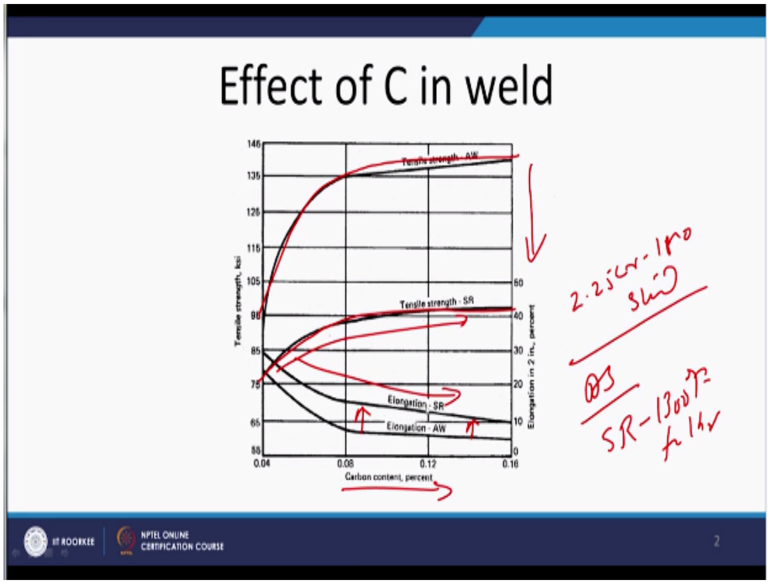

So, that is what this what we will see in this diagram this is the same diagram showing the variation in the tensile strength and ductility as a function of the carbon content for 2.25 chromium, 1 molybdenum steel . In as welded condition as well as in stress relived condition at 1300 Fahrenheit for 1 hour per section thickness. So, what it shows that is significant increase in the tensile strength in as welded condition.

But the tensile strength in stress relived 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 reliving treatment but in both the cases whether it is in stress relived 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.

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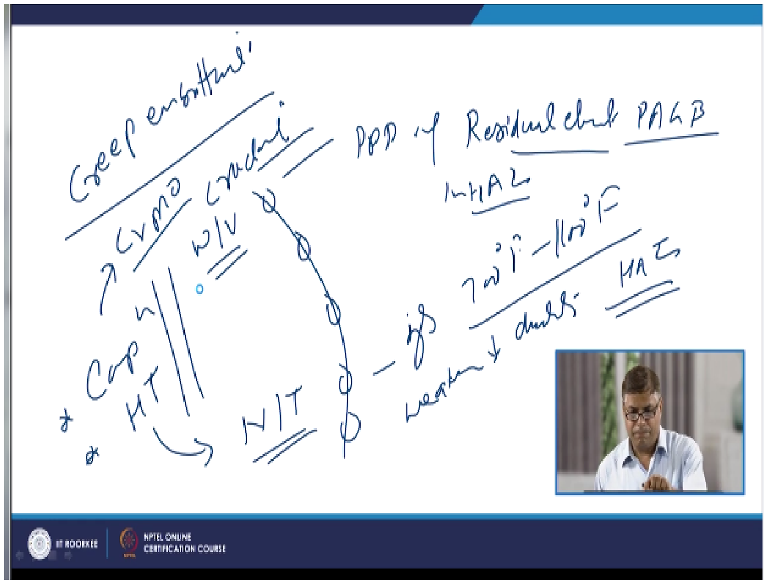

Now will be talking about the creep embrittlement basically is attributed basically it is attributed to the precipitation of residual elements at prior austenite grain boundaries in the heat affected zone. So, at the grain boundaries some of the undesirable phases precipitates and form the inter-metallic compounds and the phases which at high temperature exposure on.

Like say this temperature is around say 700 Fahrenheit to 1100 Fahrenheit, so exposure in this temperature range leads to the precipitation of the residual elements at the para 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 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 tampering treatments helps to reduce this kind of embrittlement tendency. Similarly they 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.

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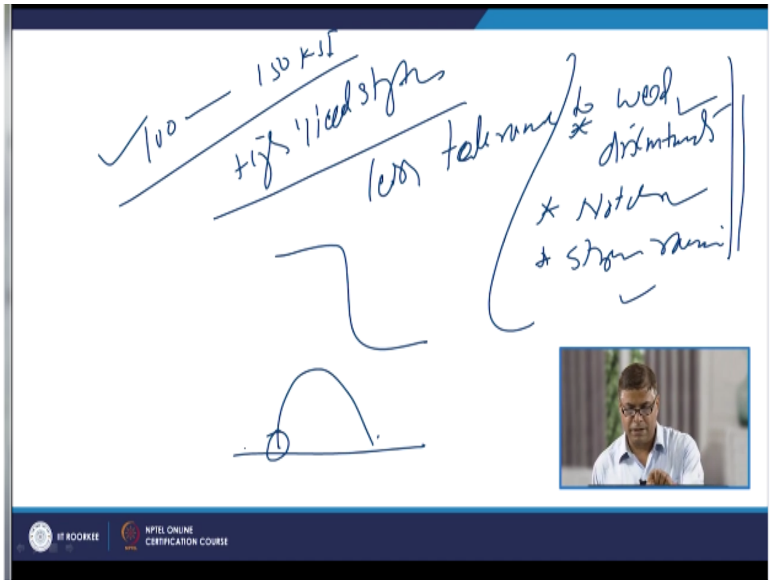

Since these steels are normally of the high strengths like 100 to 150KSI. So, because of the high yield strength of these steels their weld joints are less tolerance, less tolerant to the weld discontinuities because these easily provide the high stress concentration to promote the crack growth rate and premature failure. So, a stress notches all stress results so the failure of the weldments of the chromium molybdenum steels of high yield strength is significantly promoted by the discontinuities notches.

And all stress results in what are form they are there like sharp change in cross section or very high stress concentration of the weld. So, all these will be promoting the crack nucleation as well as their growth if these discontinuities are present.

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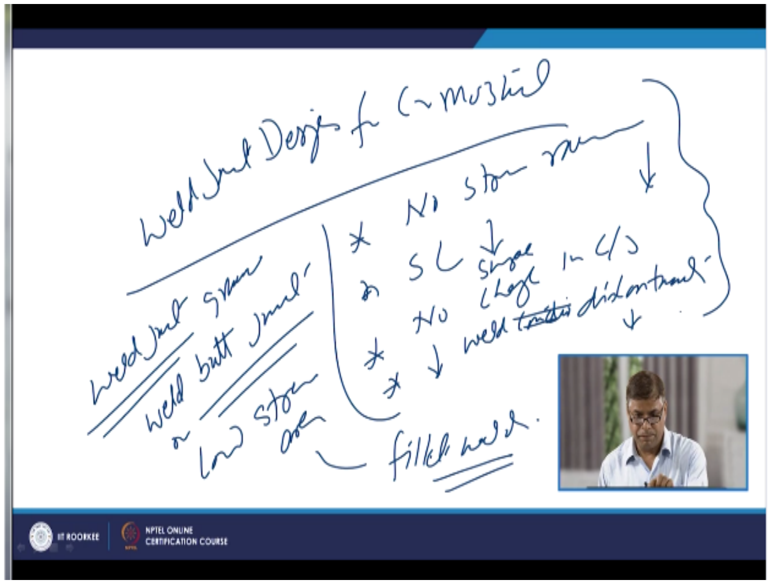

Therefore weld joint design for chromium molybdenum steel this must design must ensure that they are no stress razors, stress concentration is minimized. As well as well as there is no sharp change in cross-section at the toe of the weld or in the cross-section of the component or they are minimized the weld discontinuities are minimized.

Because these kind of the weld joints are less tolerant to the discontinuities and the stress results. And therefore we need to select such kind of the weld joint which will be reducing the tendency for all these stress results. So, normally for high strength weld joint but joint is used and if the weld joint is there in the low stress areas then only the fillet welds are used.

So, the one very simple thing is that we need to make the efforts to use the groove weld joints 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 avoided. And if the weld joints are falling in the low stress areas then maybe we can use the fillet weld joints also.

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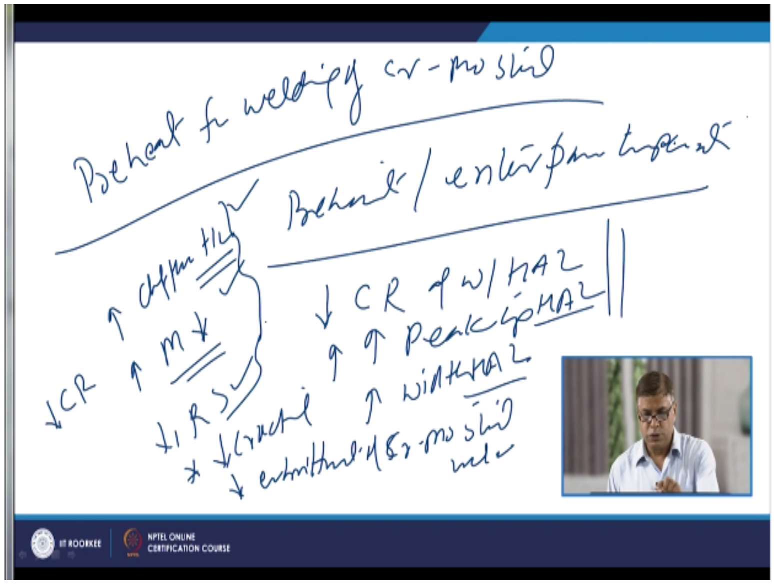

So, ~~so~~ that was about the kind of the joint design to be used. Then there is the kind of the preheat which is needed for welding of the chromium molybdenum steels. You know whenever we apply preheat, preheating of the plate or preheating of the base metal or then temperature. Whatever preheat is there the same is the inter pause temperature is used, whenever preheat is applied it will be lowering down the 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 fusion boundary. So, the heat affected zone will be experiencing the higher peak temperature as well as the width of the Hz which is formed width of Hz which is formed that increases with the increase of preheat. So, these are some of the aspects which maybe favorably 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 access 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 is reduced. So, these are the 2 very positive sides and maybe the residual stresses are also reduced due to the reduction in the kind of cooling rate which is being used.

So, these factors in combination a help in reducing the cracking tendency, help in reducing the embrittlement of the chromium molybdenum steel weld joints. So, it is important to use the suitable preheat, so that the softer phases can be form hydrogen can diffuse out and the low carbon martensite of the lower hardness is formed, residual stresses are relived. So, these factors will be helping into 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.

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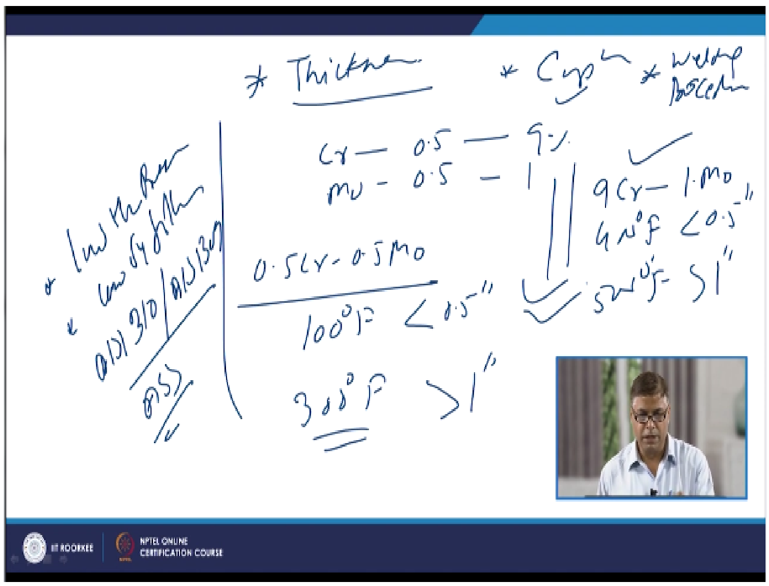

So, the kind of preheat to be used is directly found a function of the thickness and composition. So, these are the 2 main factors that affect the magnitude of the preheat thickness and the composition at the same time it the preheat temperature is also affected by the welding procedure. If we are using 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 see 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 we 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 thickness is greater than of 1 inch.

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 filler 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 develop and these factors in combination will be favorable from the welding means from the preheat point of view because even the lower preheats will be suitable to develop the weld joints.

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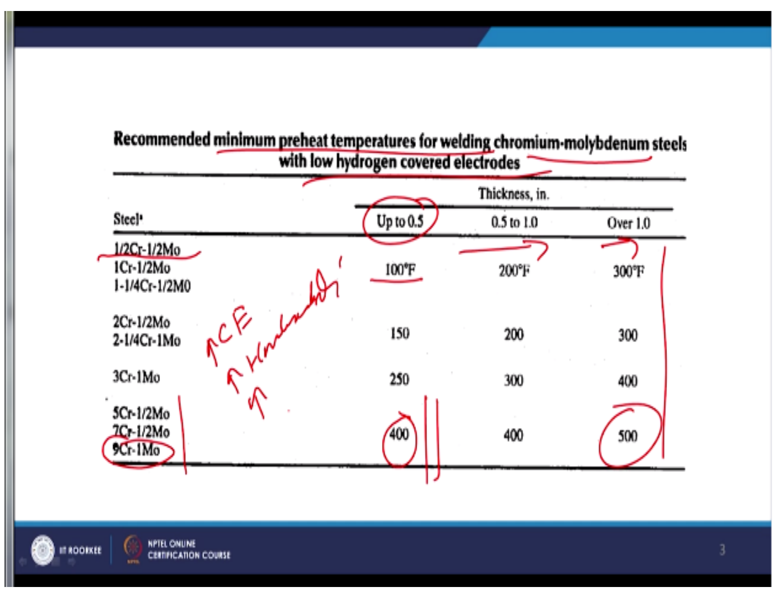

Recommended minimum preheat temperatures for welding chromium-molybdenum steels with low hydrogen covered electrodes

Steel	Thickness, in. Up to 0.5	0.5 to 1.0	Over 1.0
1/2Cr-1/2Mo 1Cr-1/2Mo 1-1/4Cr-1/2Mo	100°F	200°F	300°F
2Cr-1/2Mo 2-1/4Cr-1Mo	150	200	300
3Cr-1Mo	250	300	400
5Cr-1/2Mo 7Cr-1/2Mo 9Cr-1Mo	400	400	500

So this what we can see here this table shows the kind of preheat temperatures to be used when welding chromium molybdenum steels using the low hydrogen covered electrodes. So, 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 5 to 5, 7 and 9 chromium this preheat temperature is 400 degree Fahrenheit.

So, for higher chromium and molybdenum concentration greatly will be the preheat requirements likewise higher the thickness greater will be the kind of preheat temperature requirement. So, 400 for up to 0.5 thickness and over 1mm it is 500 degree Fahrenheit, so because increasing the chromium and an 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 temperatures. 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.