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

Lecture - 34
Weldability of Stainless Steels - II

Hello, I welcome you all in this presentation related with the subject weldability of metals and we are talking about the weldability of stainless steels. In the previous presentation we have talked about the various types of the stainless steels and the properties of the stainless steels, the way by which their weldability is affected.

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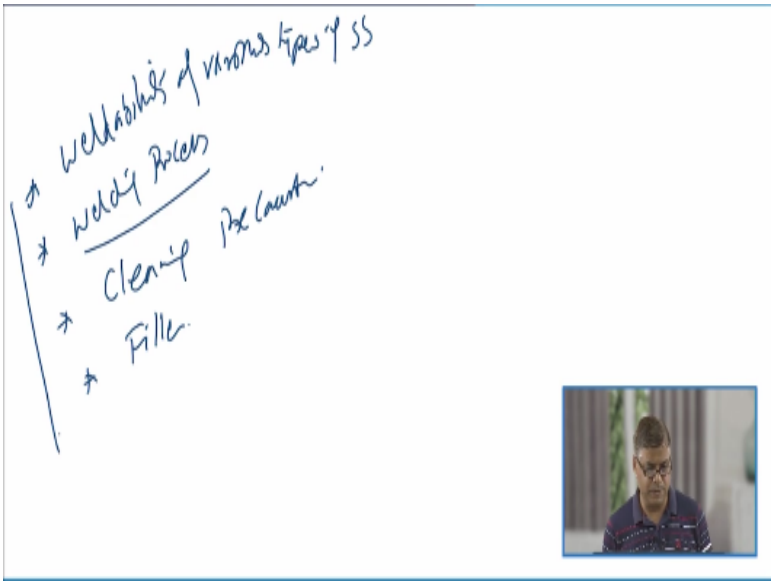

In this presentation we will basically seeing the weldability of the various types of the stainless steels. Then we will see the kind of the welding processes which can be used and the way by which these affect the properties of the stainless steel weld joints. Then we will see the kind of the cleaning precautions are needed before welding of stainless steels, the kind of the fillers which are used for the welding of the stainless steels by different processes.

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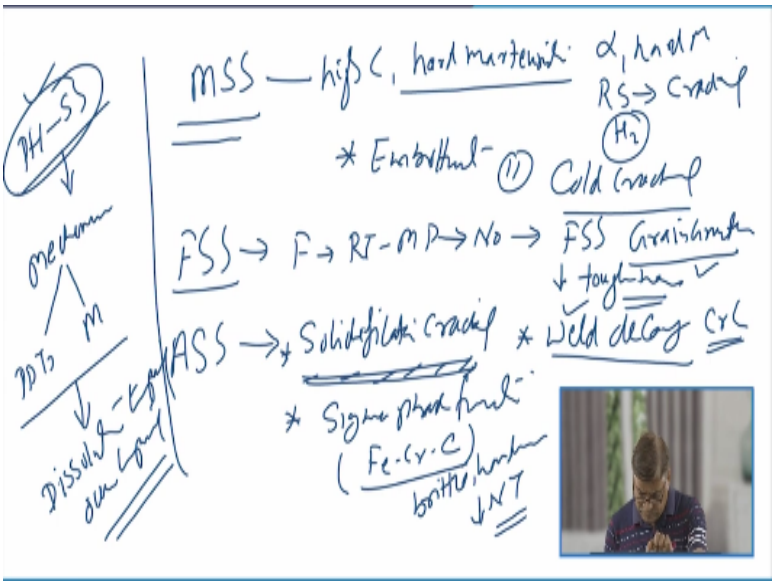

So starting with the weldability of the different types of the steels, the major factors that determine the ease of welding of the various stainless steels like martensitic stainless steels. Normally these are high in carbon and form the hard martensite. Since the thermal expansion coefficient of the stainless steels is high the hard martensite is being formed. So the residual stresses will tend to increase the cracking of these steels especially in presence of the hydrogen.

So the weldability of the martensitic stainless steel to a great extent is influenced by the embrittlement tendency due to the martensite formation and the cold cracking tendency in presence of the hydrogen and the residual stress development. Then there is the ferritic stainless steel which remains, these steels remains in ferritic state on heating from the room temperature to the melting point. So there is no allotropic behavior.

There is no change of phase and due to the application of it that is why the ferritic stainless steels experience significant grain growth in the heat affected zone. And because of this grain growth toughness of the stainless steel weld joints is badly compromised. So the grain size and the toughness will be primarily determining the weldability of the ferritic stainless steel.

In case of the austenitic stainless steel basically the solidification cracking tendency determines the weldability of the stainless steels and another common problem encountered is the weld decay. So this solidification cracking occurs due to the limited ductility, higher residual stresses at elevated temperature promotes the solidification cracking or the hard tearing tendency.

The weld decay occurs due to the formation of the chromium carbide at the grain boundary leading to the reduced corrosion resistance of the heat affected zone. So the another problem which is observed with the austenitic stainless steel is the sigma phase formation. This is primarily observed in case of the high chromium austenitic stainless steels where iron, chromium, carbon intermetallic compounds are formed in form of the sigma phase which is brittle of the high hardness.

And this in turn reduces the notch toughness of the austenitic stainless steel weld joints if the sigma phase formation takes place. While the weldability of the precipitation hardenable stainless steel depends upon the mechanism of the strengthening whether some kind of the precipitates are being formed or the martensite in very controlled way is formed.

So depending upon the mechanism whether the dissolution or tempering or over tempering of the martensite is taking place and accordingly the properties of the heat affected zone will be influenced in case of the weld joints of the precipitation hardenable stainless steels.

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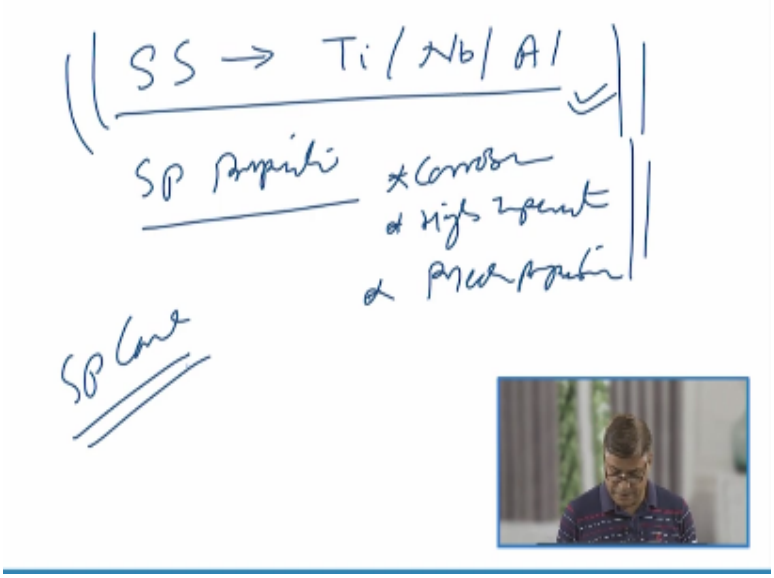

Now in these stainless steels when these are processed most of the stainless steels when these are added with the titanium, niobium or aluminium to impart the specific properties. These additions are made in stainless steels to impart specific set of the properties so that their corrosion resistance high temperature resistance in form of oxidation or high temperature strength as well as the kind of the mechanical property enhancement can be realized.

So their additions whenever these additions are made we need the special care or precautions during the welding of the stainless steels.

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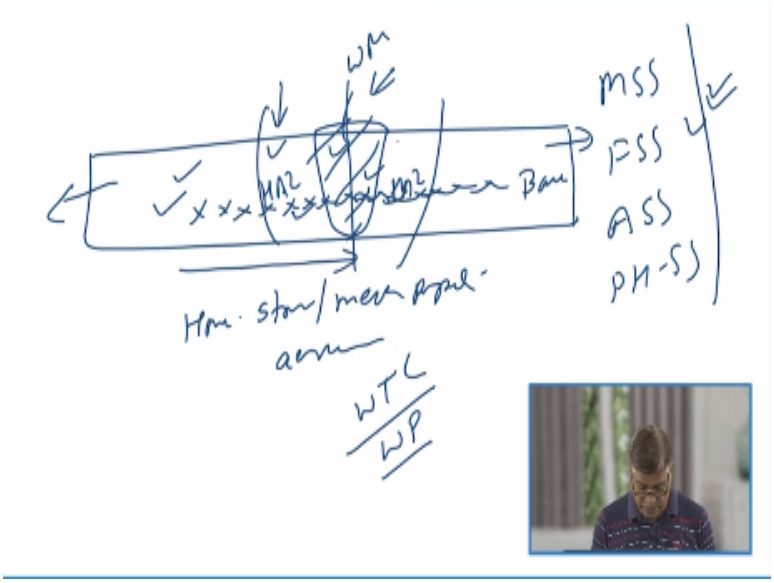

Now we will see the kind of the joint performance which is realized in case of the stainless steels since the different stainless steels like martensitic, ferritic, austenitic and precipitation hardenable stainless steels. The base and the heat affected zone HAZ and the weld metal. The properties of the joints to a great extent depends upon the homogeneity of the structure and the mechanical properties across the weld.

So what is the kind of the variation on moving from the base metal to the heat affected zone and through the weld metal and then again heat affected zone. The way by which these 3 zones of weld joint are affected due to the weld thermal cycle or weld metal which is being developed that will be determining the joint efficiency. So as per the kind of metal system there can be lot of variation in the properties of the HAZ and the weld metal with respect to the base metal.

Because all metals, all types of the stainless steels do not respond equally to the weld thermal cycle. So in few cases the HAZ is, the properties of the HAZ are compromised while in other cases properties of the weld metal are compromised. So which will be the weak zone that will depend upon the kind of the weld thermal cycle or the welding procedure being applied and the kind of the stainless steel being used.

So the zones may be strengthened in one case, and it may be, given zone may be weakened in another case as per the steel and the welding procedure. For good joint efficiency it is important that property variation across the different zones are, that property variation is limited so that the joint can really perform good as per the requirement.

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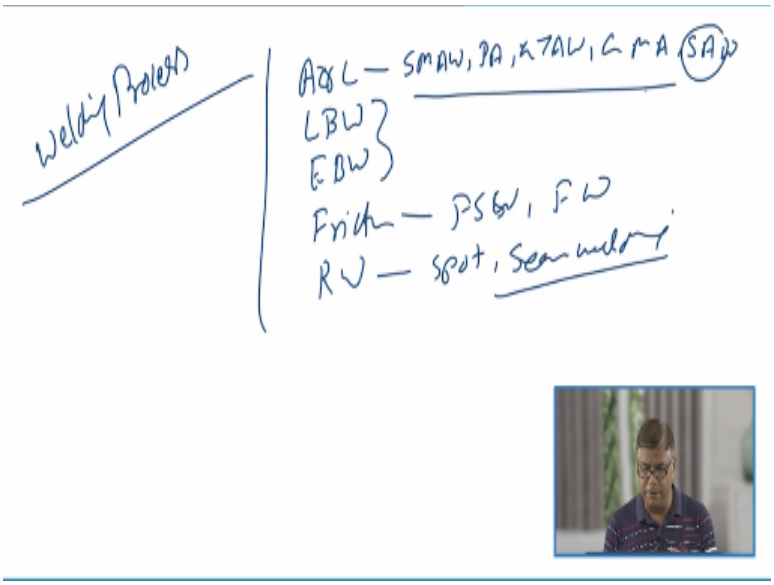

Now talking about the welding processes which are used for welding of the or the joining of the stainless steels. Now all common welding processes like arc welding processes, laser beam welding, electron beam welding then we have friction welding can be used. Resistance welding can be used. So like SMAW, PAW, GTAW, GMAW and even SAW process also can be used for welding of the stainless steels.

Laser and electron beam welding both can be effectively used for welding of stainless steels. Friction stir welding and simple friction welding can be used and all resistance spot welding, seam welding processes can be effectively used for welding. But the kind of precautions, the kind of consumables which are used will be different for the different welding processes.

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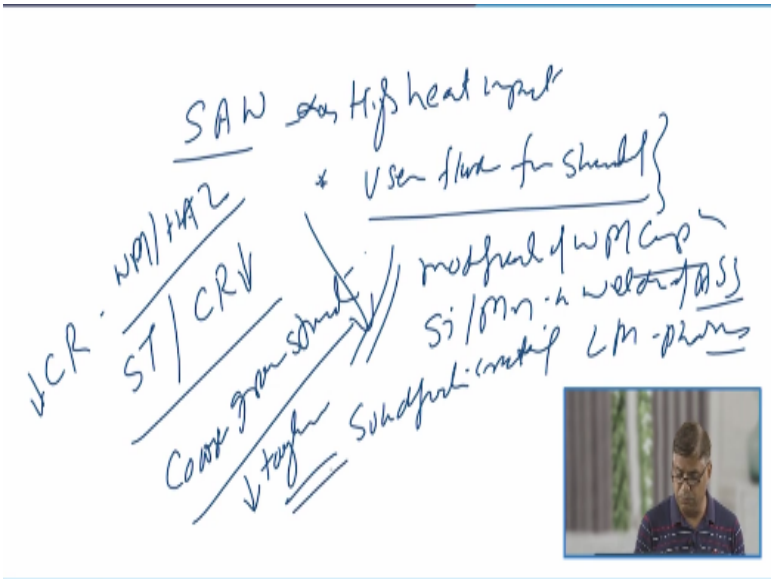

More specifically to talk about the submerged arc welding because the SMAW, GTA, and GMAW processes can be effectively used because they provide the effective shielding. In case of the submerged arc welding, this process is known to be of the high heat input process. At the same time it uses the molten flux for shielding purpose. So molten flux for shielding purpose when it is used it leads to the modification of weld metal composition in very uncontrolled way.

Sometimes addition of the silicon and manganese in the weld metal of the ASS or other stainless steels increases the tendency for the solidification cracking due to the formation of the low melting point phases in the weld metal. So the control over the composition of the weld metal becomes difficult in case of the submerged arc welding process. This is one issue related with the SAW of the stainless steels. Another one is the heat input.

Since the heat input is high so the cooling rate associated with the weld metal and HAZ will be lower and because of that solidification time will be longer, cooling rate will be lower in the heat affected zone and these combinations in the weld as well as heat affected zone leads to the coarse grain structure in the weld as well as heat affected zone and this in turn reduces the toughness of both weld as well as heat affected zone.

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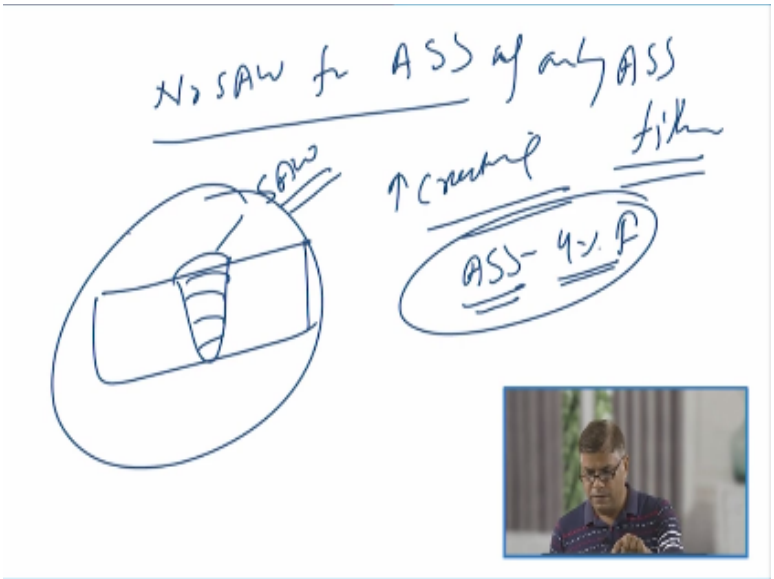

And that is why whenever possible No SAW for austenitic stainless steel welding. If only ASS filler is used because this increases the tendency for solidification cracking. If the ASS filler with the about 4% of the ferrite filler which will provide the austenitic stainless steel weld metal with the 4% ferrite in the weld zone then SAW process can be used even for the welding of the austenitic stainless steel.

In that case the grain structure will still be coarser. So that must be taken care of while developing the weld joint of the ASS using the submerged arc welding process.

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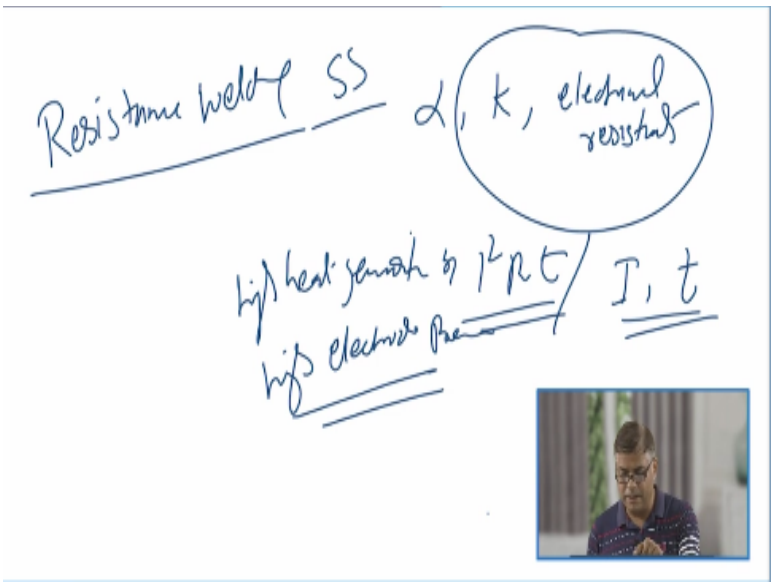

As far as the resistance welding process is concerned of the stainless steels as I have said the stainless steels they are significantly different from the carbon steels with regard to the thermal expansion coefficient, thermal conductivity and the electrical resistivity. So high electrical resistivity and low thermal conductivity of the stainless steels facilitates the high heat generation by the I square Rt principle.

So greater amount of the heat generation reduces the welding current requirement, reduces the weld cycle time, the time for which current is allowed to flow during the welding. However, due to the higher yield strength of the stainless steels we need to use the higher electrode pressure for consolidation during the resistance welding process as compared to the carbon steels.

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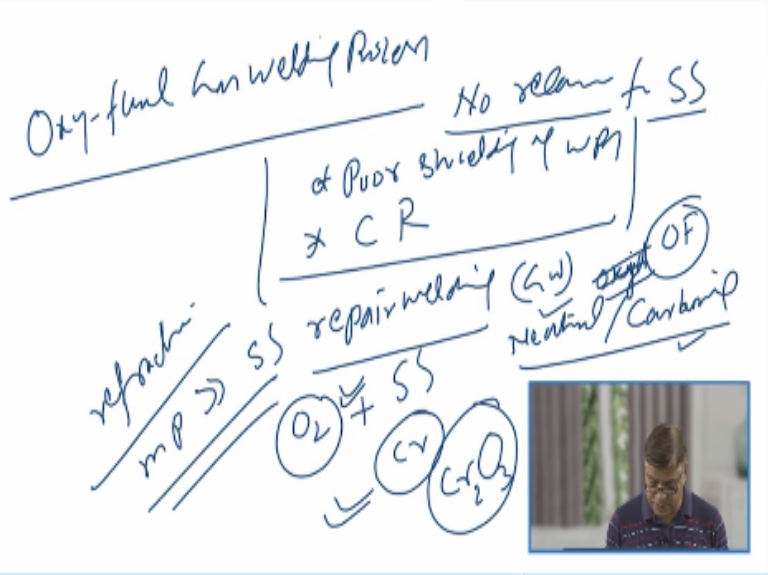

On the other hand the oxy-fuel gas welding process, this process is not recommended for welding of the stainless steels because of the poor, very poor shielding of the weld metal. So the protection of the weld metal from the atmospheric gases in case of the oxy-fuel gas welding process is limited and the heat input is also high. So that in turn reduces the cooling rate.

So not recommended for welding of the stainless steels except when the repair welding is to be carried out the gas welding can be used. In that case if at all the repair welding is to

be performed then instead of the oxidizing flame we use the either neutral flame or carburizing flame or reducing flame.

So instead of oxidizing flame carburizing or neutral flame is used because the presence of excess oxygen during the repair welding of the ASS the chromium present will form the chromium oxide and that in turn Cr 2O 3 or something else will be formed so that will be, this chromium oxide is refractory in nature and is having the melting point, chromium oxide is having the melting point greater than the melting point of the stainless steel.

So it does not melt during the welding and it may be present in form of the inclusions or it may interfere during the melting of the base metals. So we need to avoid the presence of excess oxygen during the oxy-fuel welding using either neutral flame or the carburizing flame. So these are the two points as far as the oxy-fuel welding is concerned.

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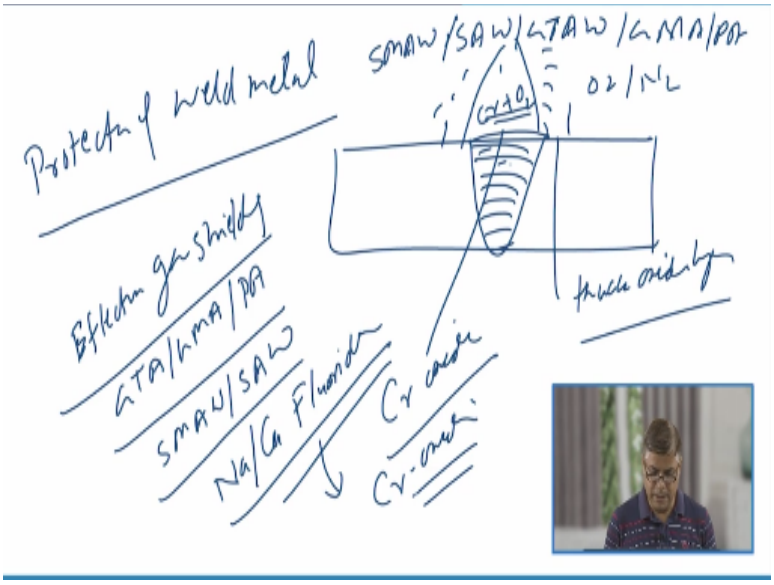

Now the protection of the weld metal is concerned, for the purpose of the protecting wave, protection is important. You know the stainless steel is subjected to the fusion welding using the different types of the welding processes like SMAW or SAW or GTAW or GMAW or PAW. In all these processes if the protection by the heat source like arc, if the protection is not proper then oxygen and nitrogen present will interact with the molten metal.

Interaction of the oxygen with the chromium in the molten state or the chromium in the zone which is being heated will be leading to the formation of the thick oxide layer. So the formation of the chromium oxide layer in the molten metal or thick oxide layer in the vicinity of the weld joint, both these are undesirable because of their refractory nature these will not be melting and getting fused with the weld metal.

These will act as inclusion. This may interfere with the melting of the base metal. So the weld metal must be protected from the atmospheric gases so that the chromium oxide formation can be avoided. And for this purpose the various approaches are used. As per the welding process like effective gas shielding plays a very crucial role in protecting the molten metal and the base metal from the atmospheric gases like in case of the gas tungsten arc welding, gas metal arc welding or the plasma arc welding processes.

But in case of the shielded metal arc welding, submerged arc welding special constituents like the sodium or calcium fluorides are used so that it can dissolve the chromium oxide which is being formed during the welding of the stainless steel. So the fluorides effectively remove the chromium oxides if these are being formed during the welding of the stainless steels.

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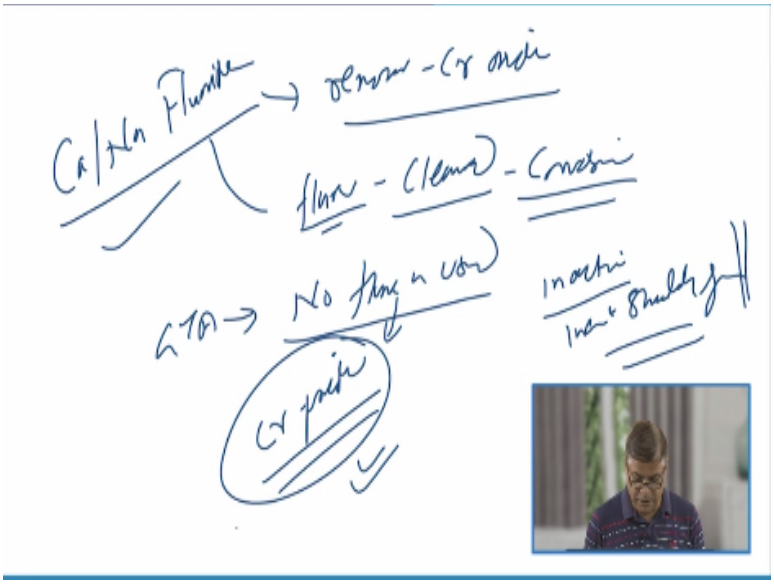

But the calcium or the sodium fluorides which are being added to remove the chromium oxides, the fluxes where such kind of chlorides are present must be cleaned because these are very corrosive in nature. So effective cleaning of such kind of the fluorides become crucial. In case of the GTA and the other gas shielding based methods, no flux is used.

Because in those cases the protection to the weld metal as well as the protection to the heat affected zone or the zone nearby the weld metal is provided by the inactive or inert shielding gases. So we need, since there is no mechanism to remove the chromium oxide if it is being formed we need very proper cleaning of the base metals before welding.

Because if the chromium oxide is present it will not be taken care of by the fluxes since there is no use of the flux in GTMA and GMAW process. So more effective cleaning becomes crucial in case of the GTA and the GMAW process.

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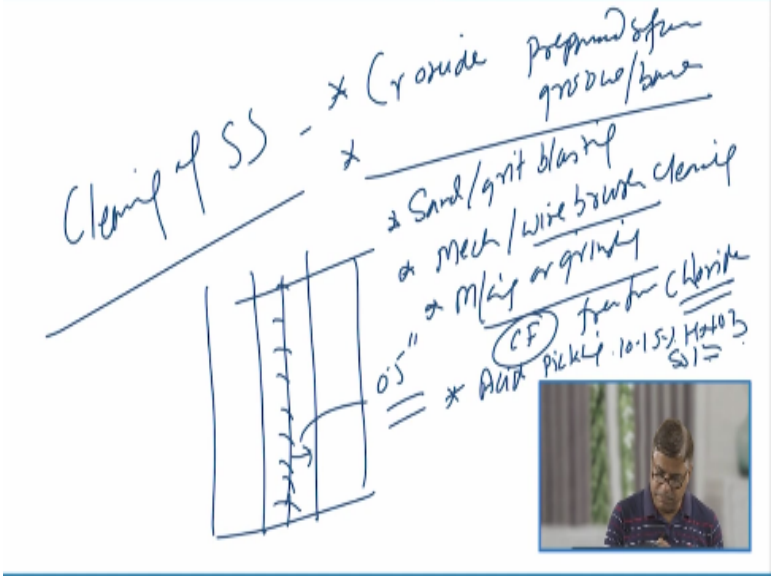

As far as the cleaning is concerned, cleaning of SSA is very crucial especially to remove the chromium oxide if it is present on the prepared surfaces like groove as well as the base metal. So if this is the base metal so the groove being formed should be cleaned and the distance up to the minimum 0.5 inch from the grove surfaces should be prepared so that, should be cleaned so that the chromium oxide from the base metal or in vicinity of the weld metal can be removed.

There are various kind of the methods which are used for cleaning purpose and these methods include like the sand or grit blasting. This is one mechanical or wire brush cleaning. The brush which has not been used for any other purpose of the cleaning then that kind of brush is used for cleaning purpose.

Then machining and grinding of the stainless steel provided the cutting fluid being used for machining or the grinding is free from chlorides because these chlorides are very sensitive for the corrosion of the stainless steels and there is one method which is very effectively used for removing the oxide layer is the acid pickling. So basically the 10 – 15% HNO3 solution is used for removing the oxide layer from the surface of the stainless steel so that the presence of the chromium oxide can be eliminated.

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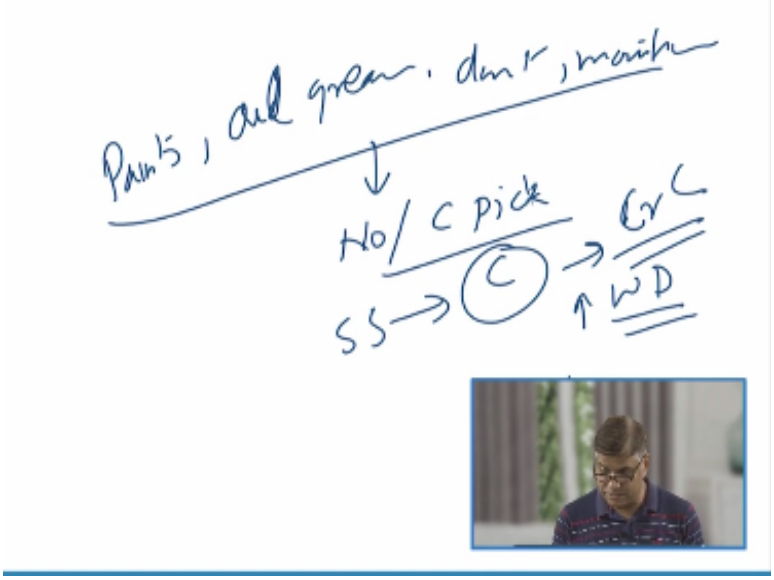

Apart from the removal of the chromium oxides effective cleaning for removing all paints, oil, grease or dust, moisture this also should be ensured so that there is no source of the hydrogen, hydrocarbons and there is no possibility for carbon pickup. Because if the stainless steel picks up the carbon during the welding it will promote the formation of the chromium carbide in the weld as well as the heat affected zone.

And which may promote the weld decay tendency that in turn will be reducing the corrosion resistance of the weldment in general.

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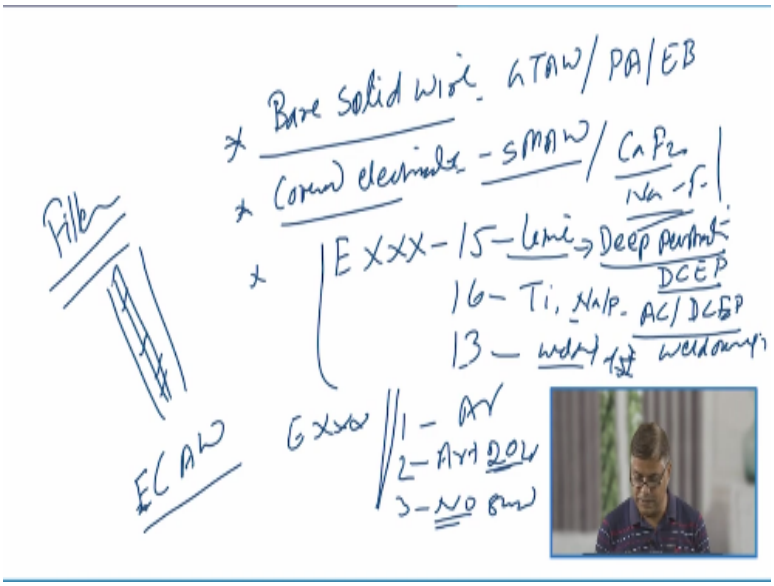

Now talking about the kind of fillers which are used for welding of the stainless steels, there are 3 types of the fillers. One is like the bare solid wires. These are normally used with the non-consumable welding processes like the gas tungsten arc welding, plasma arc welding and electron beam welding processes. But there is another category like where covered electrodes are used.

So in this case basically the stick electrodes are there which are primarily used in the shielded metal arc welding processes and there we may add like the calcium fluoride or the sodium fluoride kind of the elements for the better arc stabilizations and there are like the 3 types of the electrodes which are commonly used in category of the shielded metal arc welding process. One is like EXXX – 15 then 6 and then there is 13.

These are the three most common types of the electrodes based on the kind of the constituents which are being used in the coating material. So it primarily contains the lime which is helpful in realizing the deep penetration. So when the groove is narrow the EXXX – 15 lime based electrode is used. The second one is and it uses basically the DC electrode positive polarity.

In case of the E -16 it uses the titania and other arc stabilizers like sodium and potassium. So it can work with both AC as well as DCEP. It is used for the weld overlays or the weld surfacing applications. Then there is one more electrode 13 which is mainly used for the welding of the steels used for the structural applications. Now, then we have another type of the electrodes which are used for the flux code arc welding purpose.

And these are designated like EXXX – 1, 2, 3. So which means no shielding S 3s for the no shielding gas used. Second is the case where argon plus 2 % oxygen is used and in the case one where just argon is used for the welding purpose along with the fluxes which are there in the core of the electrode in case of the FCAW process. Now I will summarize this presentation.

In this presentation basically I have talked about the various welding processes, the kind of cleaning methods which are used and the kind of flux which are available for the welding of the stainless steels. Thank you for your attention.