Joining Technologies of Commercial Importance
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Lecture - 17
Soldering and Braze Welding

Hello, I welcome you all in this presentation on 17th lecture related to the joining technologies for the metals and in this presentation, I will be talking about another solid-liquid joining process that is called braze welding.

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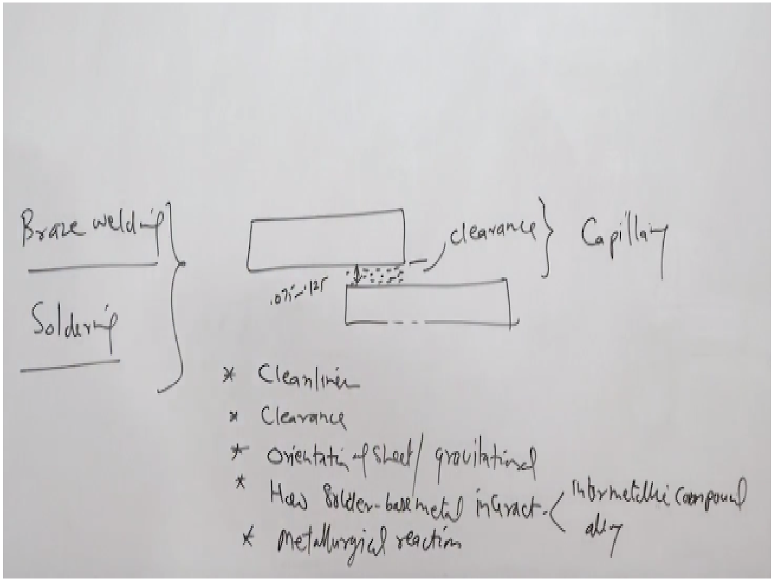

And apart from braze welding, I will also be talking about little bit the soldering about which basic principle of the soldering I have talked yesterday, but some of the points were left so those I will be taking first before coming into the braze welding; however, both these processes are the solid-liquid processes in which the base metal to be joined remains in the solid state while the filler metal is brought in the liquid state for development of the joint.

The thing which is important like brazing in case of the soldering also, the gap between the components to be joined, which is called clearance must be very closely maintained, which is 0.075 to 0.125. This gap plays a big role in achieving the required capillary action by which material or the solder material is sucked inside between the plates or sheets to be joined by the capillary action and gets distributed uniformly.

However apart from this clearance, there are other factors also which effect that how effectively or uniformly the solder material spreads in between the sheets over the faying surfaces, which subsequently on the solidification will be developing the joint in form of the solder joints. So here we can say the one is the cleanliness of the surfaces apart from the clearance will see that what is the orientation of the plates? Where this has to get spread?

If it is horizontal probably the gravity will not be playing a big role, but if the gap where the seeds are oriented in different angle and in this situation then the spreading will be governed by the angle at which the plates are oriented. So indirectly we can say that either the orientation of the plates or the sheets and this effect is primarily due to the gravitational force so how the gravity is assisting or resisting in spreading or distribution of the solder that will determine the uniformity and ease of the spreading of the solder.

Apart from that will also see that how the solder and base metal interact with each other, base metal interacts or react with each other, which maybe in formation of the inter-metallic compound at the interface or it may get alloyed. So the way by which solder interacts with the base metal that also affects the spread-ability and the metallurgical interactions between the solder and the base metal.

So metallurgical we can say the reactions between the base metal and solder will also be affecting the spread-ability. So we have to make sure that the surface is clean and the base metal and the solder are compatible with each other. So that the spread-ability is not very adversely affected in uniform distribution of the solder as well as the sheets are oriented favorably which will help in uniform distribution of the solder besides controlling the clearance properly as well as maintaining them in very clean condition.

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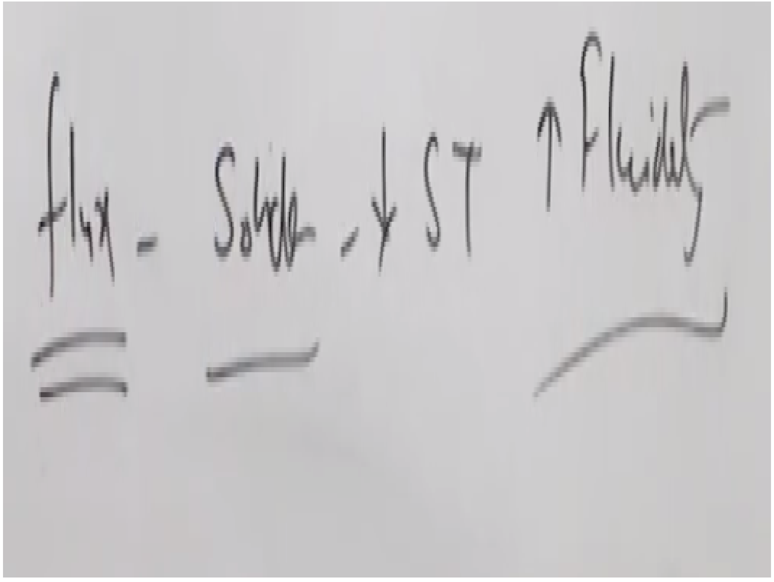

Additionally, the use of proper flux also helps in improving the spread-ability because the flux reacts with solder and which helps in reducing the surface tension and increasing the fluidity, so improved fluidity helps in improving the spread-ability of the solder.

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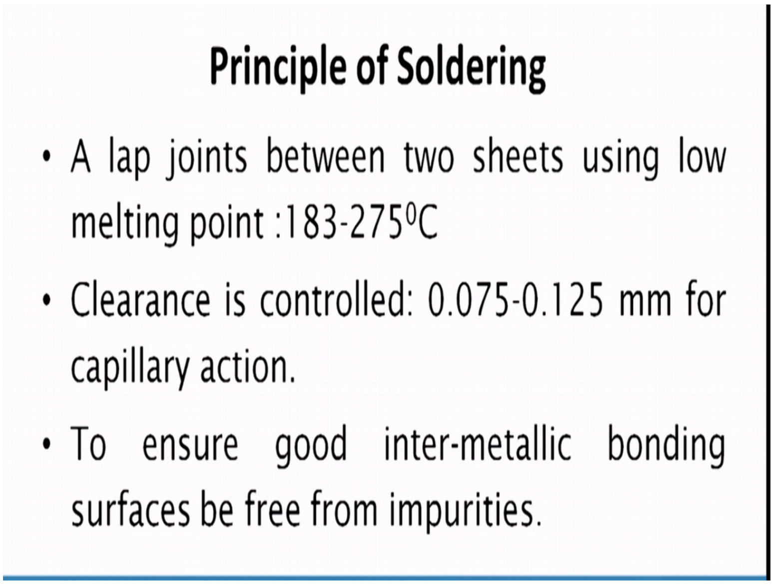

So this is what will see that soldering is mainly done in lap joint configuration between the sheets for developing the joints between the sheets using the low welding point material having 183 to 175 degree centigrade temperature range of the melting in degree centigrade and clearance very close controlled. Clearance is maintained especially for achieving the capillary action so that the things can get distributed uniformly and to ensure the good inter-metallic bonding so the surfaces must be free from the impurity.

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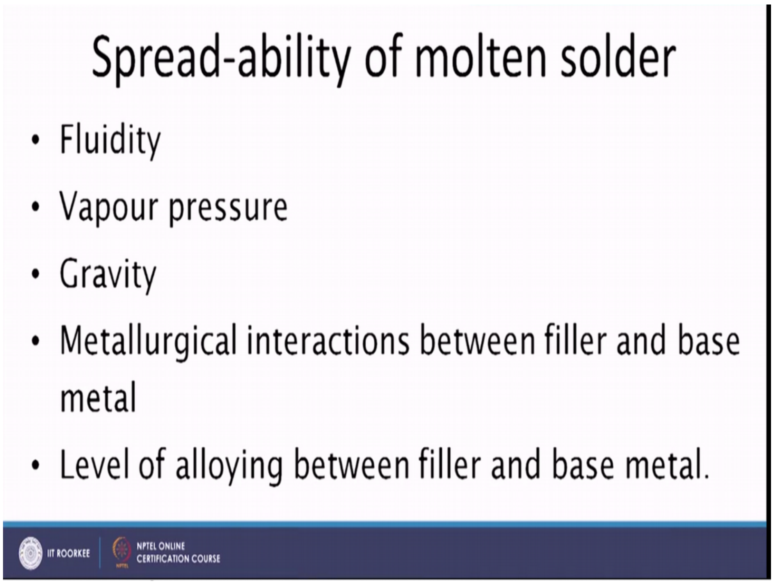

So that the inter-metallic bonding can takes place and the factors that affect the spread-ability of the molten solder between the sheets is governed by us. I have explained the fluidity, vapour pressure, gravity of all the orientation of the plates and the kind of metallurgical interactions between the filler and the base metal takes place whether it is by the inter-metallic formation or by alloying with the base metal.

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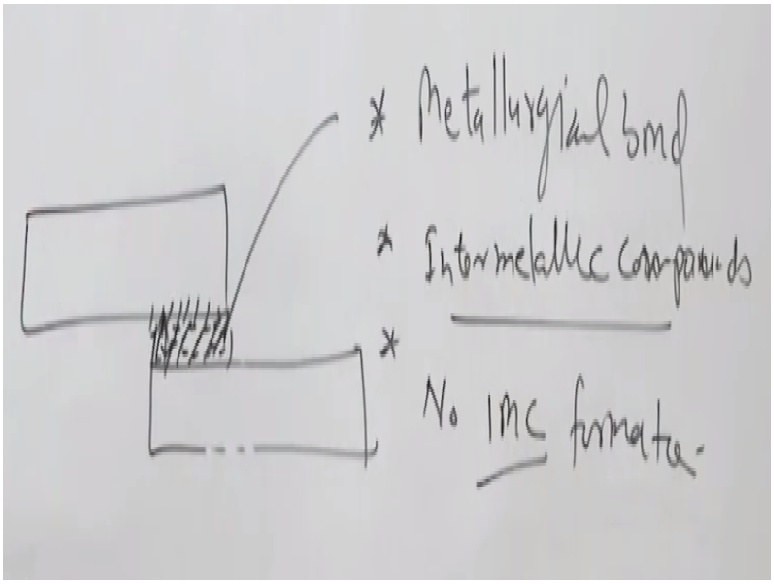

So here will see that what are the factors that govern the strength of the solder joint? So once the solder is spread uniformly between the sheets after the solidification, it will produce the joint, but the strength of the joint depends upon the three factors, first is the kind of if the metallurgical bond is developed and it offers very good strength and metallurgical bond maybe in form of formation of the inter-metallic compounds between the sheets.

And if in case no inter-metallic compound formation, then the strength of the joint solely governed by the adhesion the way by which the solder metal interacts and closes the gaps at the surface of the work piece or the sheets.

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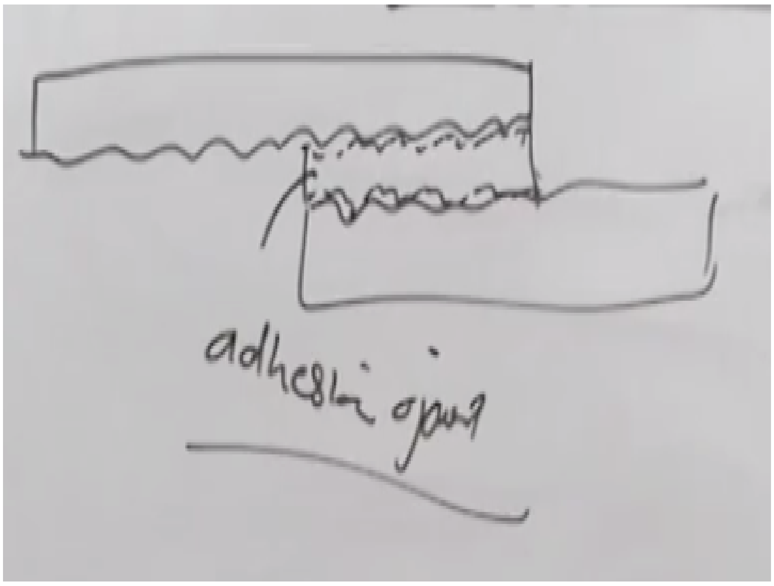

For example, if the sheets are like say all the sheets are the real surfaces will have peaks and valleys at the surface and like this on the other side so the solder will be filling all these gaps peaks and valleys present on both the sides and this is how after the solidification, they will be forming the adhesive or adhesion joints you can say.

So here there is no metallurgical bond, but mainly by the adhesion or the kind of connection between the sheet metal and the solder the joint strength is governed, but in fact the filler metal is solder, which itself is of the lowest strength so not very high strength of the joint is obtained this case. So in case when the no compound is formed at the interface then strength is largely governed by the adhesion.

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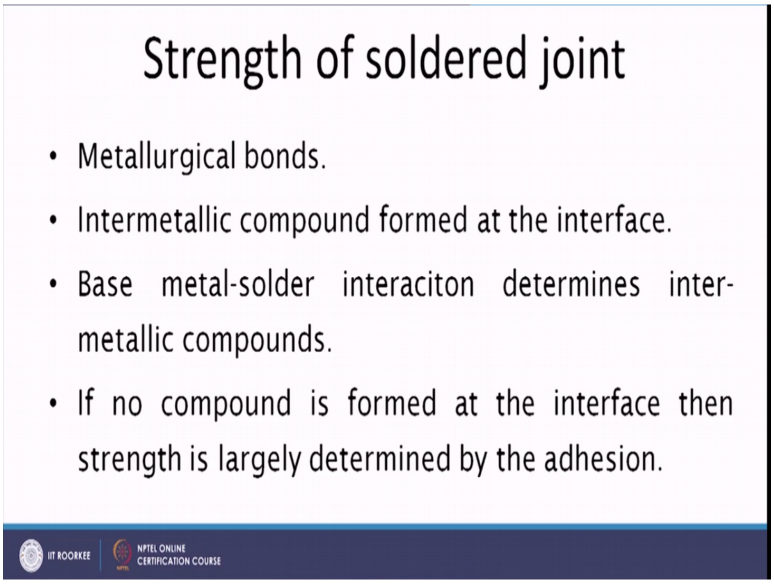

And the base metal solder interaction determines the inter-metallic compound formation and once if the inter-metallic compounds are formed at the interface then normally good metallurgical bond is obtained.

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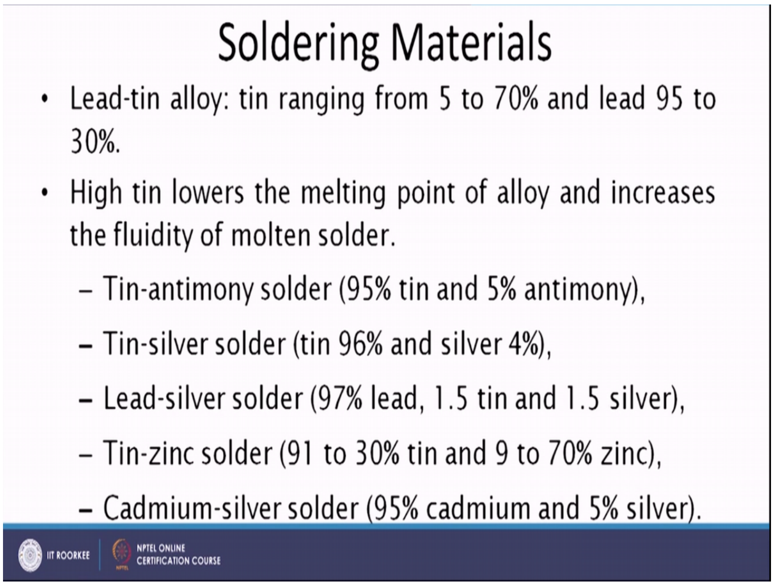

The kind of metal systems, which are used for making the solder, is the combination of lead and tin and the different amounts of the lead and tin is used for developing the solders. For example, in lead the tin ranging from 5% to 70% and lead 95% to 30% means varying amount of the lead and tin is used in the systems. However, the high tin lowers the melting of the alloy and increases the fluidity.

So tin is good in that way. It lowers the melting point of the solder and improves the fluidity, but in these solders, the main issue is about the lead being a poisonous. At high temperature, it offers the poisonous gases, which are harmful for the health of the human being during the operation.

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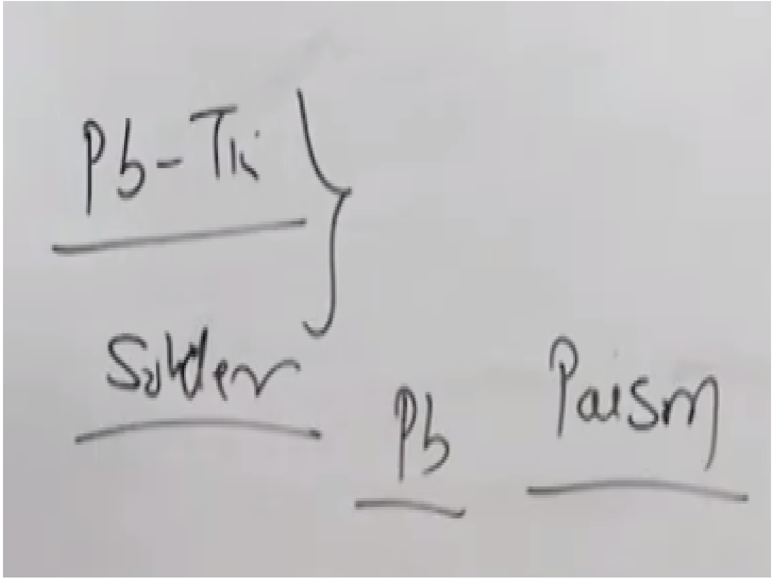

So now the leaded solders are now being banned also and alternative solders are being developed or you can say the lead-free solders are being developed for the purpose because the lead being poisonous it is harmful for the health of the operator.

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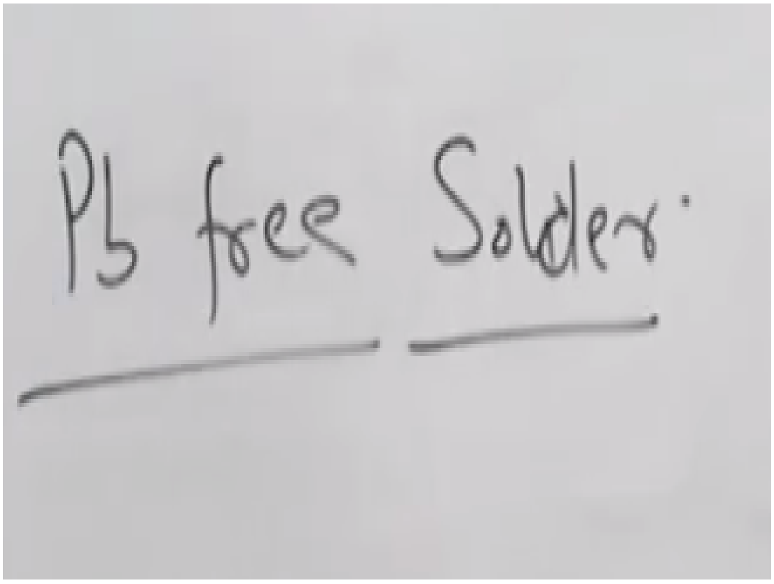

So basically the efforts are being made nowadays for developing the lead-free solders. The other solders which are used like tin-antimony solder, tin-silver solder, lead-silver solder, tin-zinc solder and the cadmium-silver solder. So this means efforts have been made for coming over the solders, which are free from the lead so that the poisonous effect related with the lead can be avoided in the soldering process.

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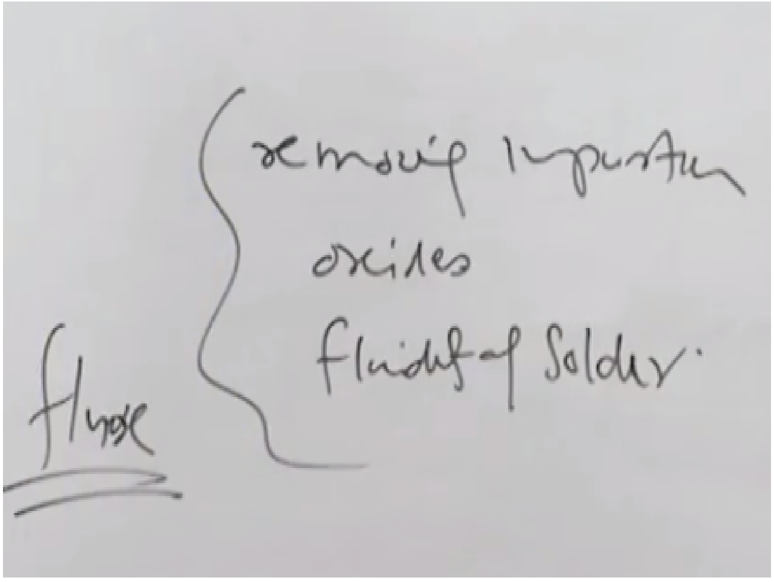

Apart from this, if will see for achieving the specific purposes like removing the impurities, oxides if they have been formed, improving the fluidity of the solder so that the spread-ability can be improved, the fluxes are used so the various types of the fluxes are used and they are used in the different forms.

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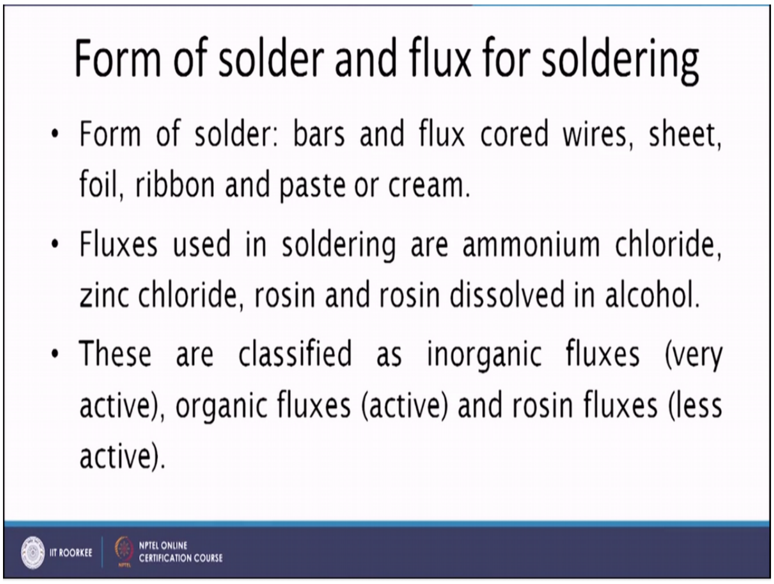

So first will see that the solders maybe used in form of bars and the flux cored wires or sheets, foils, ribbons etc and the fluxes used for the soldering process maybe ammonium chloride, zinc chloride, rosin or rosin dissolved in alcohol. These fluxes are classified as inorganic fluxes, which are highly active and organic fluxes, which are active reasonably and rosin fluxes, which are less active.

So depending upon the method, which is used for the purpose of heating of the base metal, different soldering methods have been developed. These methods primarily differ in the way by which heat is applied for heating the base metal so that the solder can be brought to the molten state subsequently during the operation.

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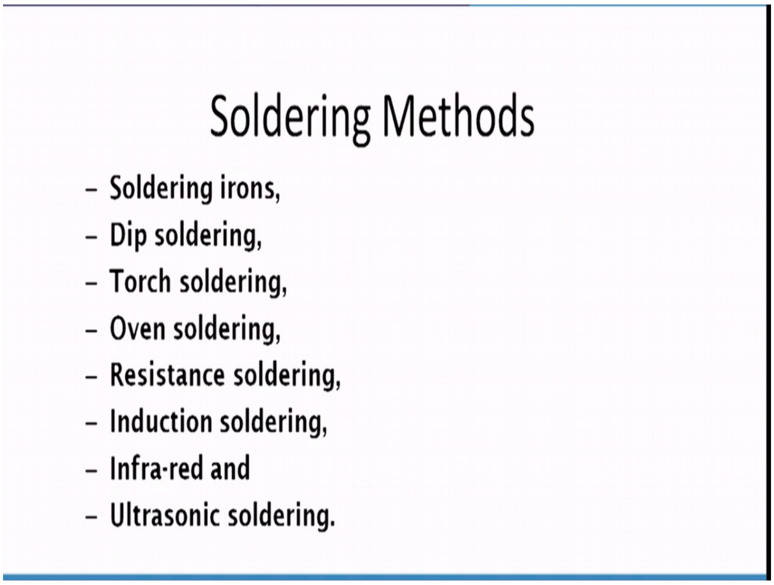

So depending upon the heating method like soldering iron, dip soldering, torch soldering, oven soldering, resistance soldering, induction soldering, infra-red and ultrasonic soldering. So these methods primarily differ in the way by which the heat is applied to the base metal and the way by which solder is placed or applied between the faying surfaces to be joined.

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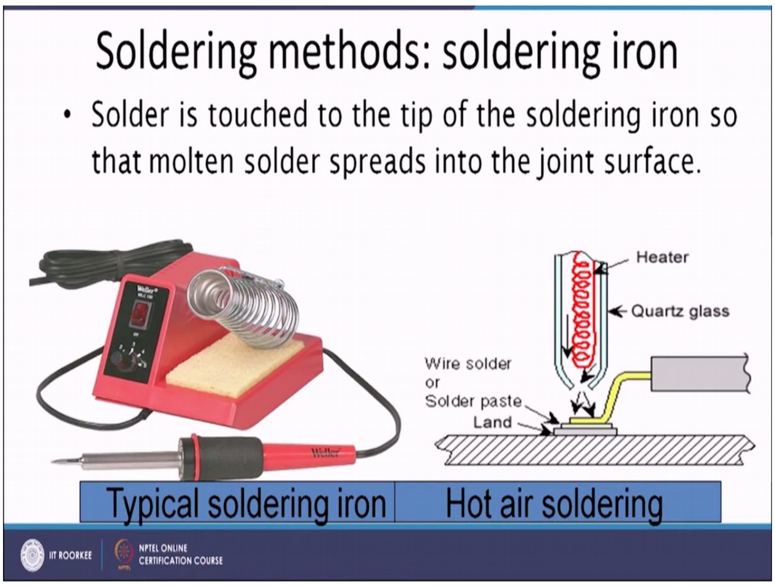

So here will see the two methods like soldering method using soldering iron is the typical soldering iron. So here it is very low capacity kind of the heating arrangement where once the soldering iron is heated, then solder is applied at the tip of the iron and then it is placed at the place where it is required. In the hot air soldering like hot air is applied over the surface once the flux and solder is placed between the sheets of where the joint is to be weighed then hot air is applied for the melting of the solder.

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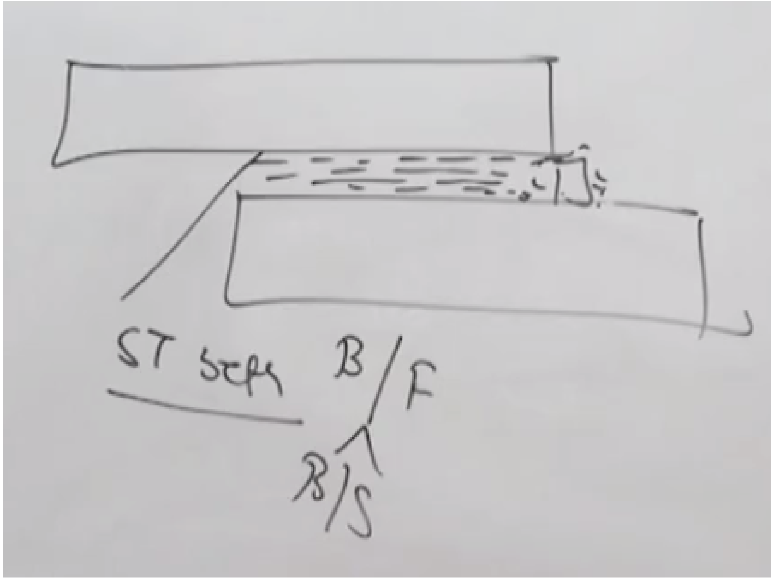

Then, once the solder is placed like say during the operation how does it work, like say this is the solder, flux is also applied so basically all will be reaching to the molten state here, the flux will also melt, solder will also melt. So depending upon the surface tension between the base metal and flux and base metal and solder, so the surface tension between the base metal and the flux being lesser than that between the solder.

So the flux is pushed out in course of the soldering and the liquid solder will be pushing it outside while interacting with molten metal.

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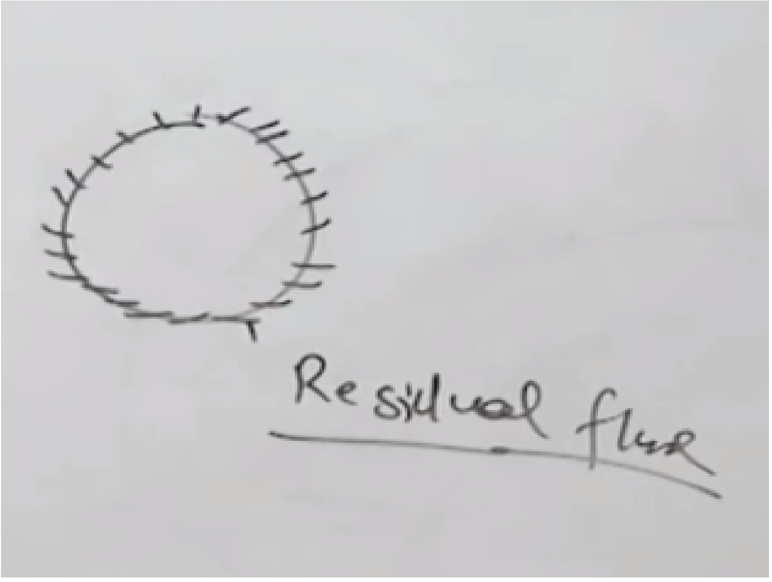

So we will see that say if this is the circumference where the joint is made, then all the flux will be segregated at the outside because it is pushed in course of the soldering process. So this is called residual flux, which must be removed because this flux being corrosive in nature.

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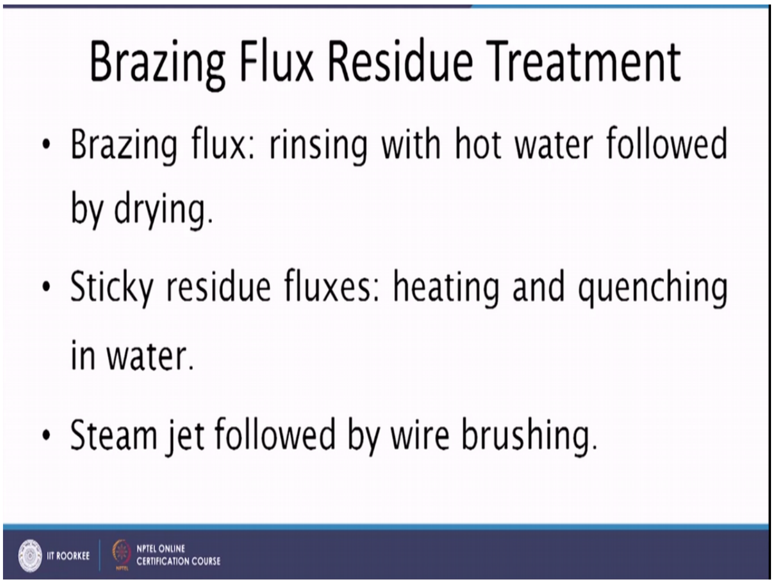

So the different methods are used for removal of the fluxes like bracing fluxes are removed by rinsing with hot water followed by the drying and sticky residue fluxes are removed by thermal shock like heating followed by the water quenching and steam jet followed by wire brushing is also used.

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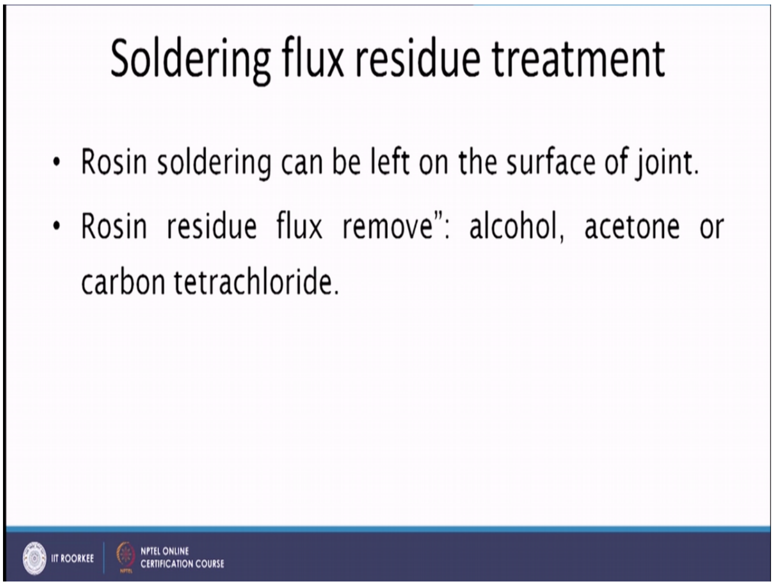

For removing the soldering fluxes residue treatment like rosin soldering fluxes can be left on the surface because they are not considered to be the corrosive in nature and the rosin fluxes, which is required to remove when alcohol acetone or carbon tetrachloride can be used for this purpose. Now coming to the braze welding process, so the brace welding is combination of the brazing as well as the welding process. It has lot of similarities with both processes.

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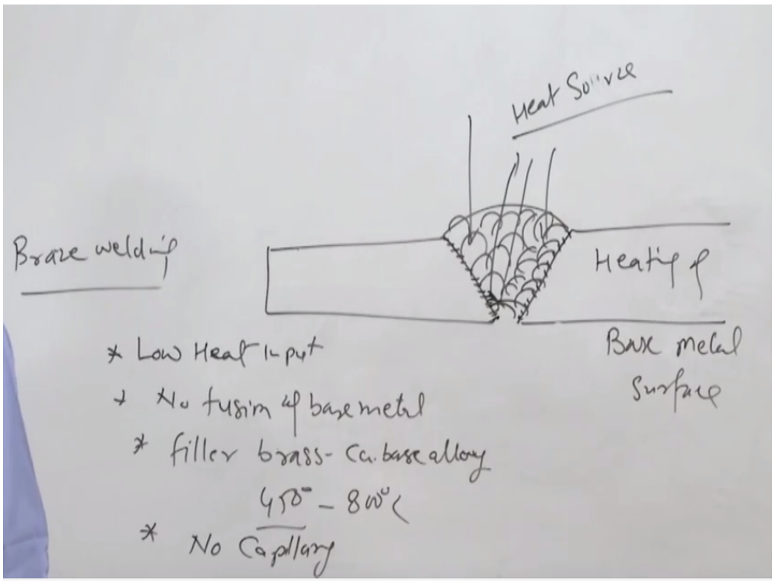

Here the principle of the braze welding is like this wherein the components to be joined are first prepared for the surfaces, so a groove is made between the components to be joined. Of course all those benefits related with the braze welding whatever were available for the brazing are also available in the braze welding.

Like the heat input is low, so h net or low heat input, no fusion of base metal and the filler is invariably brass so which is copper base alloy offers much better strength. Obviously, the melting point is more than 450 degree centigrade to the 800 degree centigrade. The thing is here, in this process there is no capillary action kind of thing, it does not rely on the capillary action for distribution of the brazing material, which will be applied.

So how the process works in. The components to be joined are first prepared for the edges faying surfaces, so there is faying surfaces so this kind of faying surface is prepared by machining. So this is called edge preparation. So one groove is made, once the groove is made then the surfaces are heated, so using suitable source applying the suitable heat source, the faying surfaces are heated and once the faying surfaces are heated, the brazing filler rods are applied over the faying surfaces.

So the brass will be melting and filling this gap one by one. So basically the gap is filled not by the capillary action, but by melting of the filler, which is applied of course after heating of the base metal surfaces. Once it reaches to the surface at high temperature, the filler rods are applied over the faying surfaces, so the filler rods melt and they fill up the gap. In this case, if we see there is no role of the capillary action, filler rod whatever is applied melts at.

Obviously this is a brass so melting temperature range means liquidus temperature range is from 450 to 800 degree centigrade and the filler metal, which is used as a braze and there is no fusion of the base metal or any fusion of the filling surfaces takes place and the heat input is very low.

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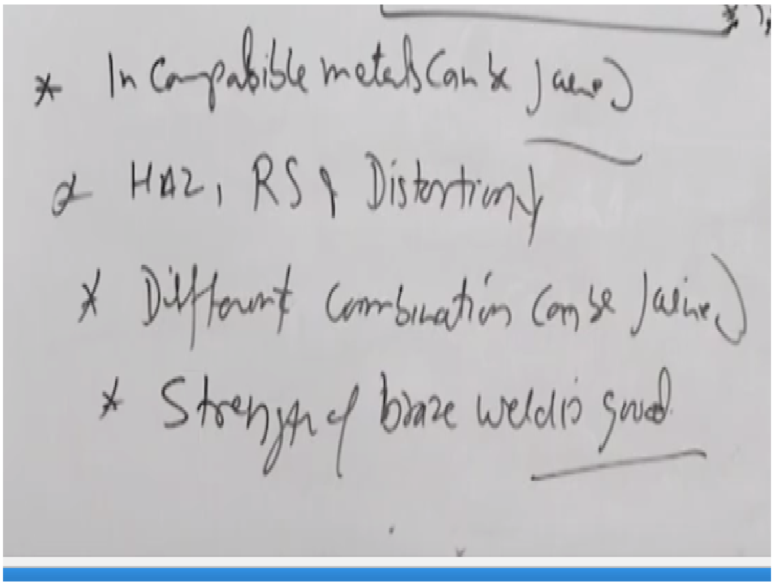

So because of these 3 or 4 points, what we get that incompatible system metals can be joined. This is one thing because there is no fusion and the second is heat input is less so the HAZ size, residual stresses and the distortion tendency is very less in case of the brazing and soldering and very different combinations can be joined by the braze welding and further the strength of the braze is much better as compared to what is absorbed by the solders.

So the strength of the braze weld is reasonably good. So now we will come to further details related to braze welding.

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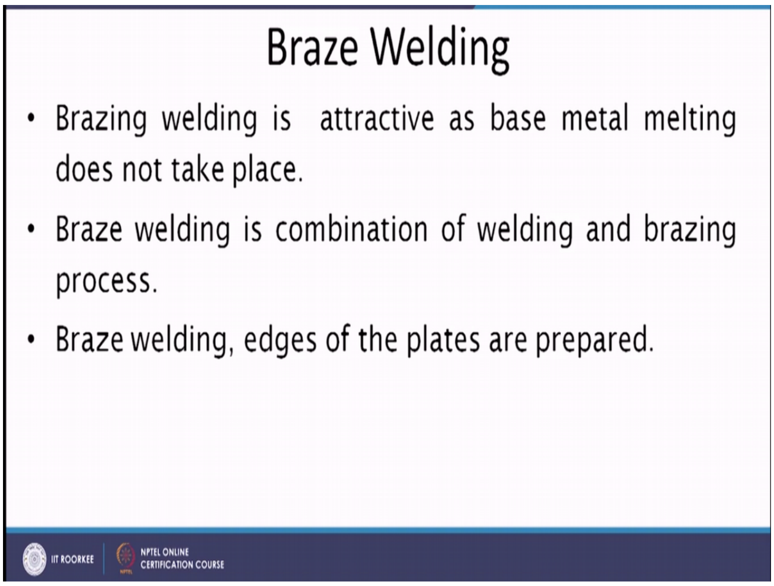

The process is attractive as the melting of the braze metal does not take place, braze welding is a combination of the brazing and welding and the braze welding requires the edge preparation. If you have to really distinguish between the braze welding and the welding.

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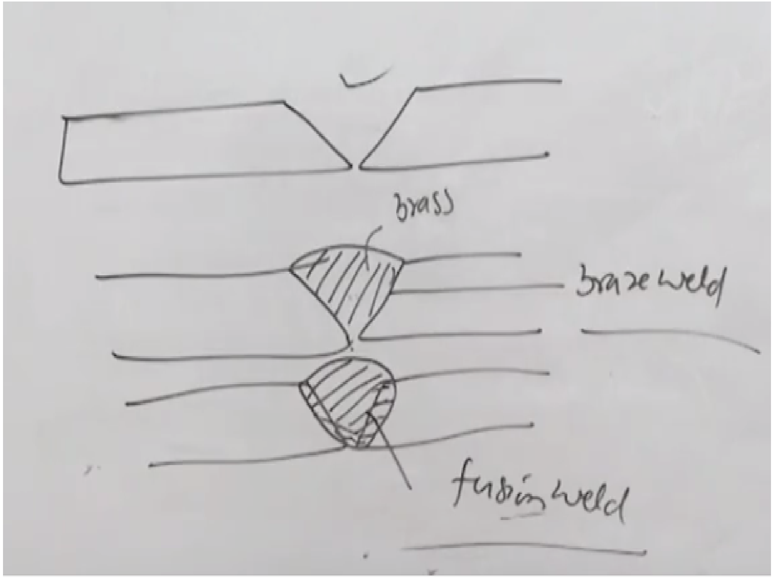

Then we have to see on simple diagram, which will clearly indicate that if this is how the plates have been prepared for developing the joint, in case of the braze welding, the surface of the base metal remains intact and rest of the gap is filled in by the brass. While in case of the welding, the faying surfaces melt and the geometry of the edges of the plates gets modified like this.

So here the straight edges, which were prepared by machining are eliminated, they are brought to the molten state and this is typical in case of the fusion welds, this is in case of the braze welds and this is the like say V- groove prepared for developing either fusion weld joint or the braze weld joint. So in case of the braze weld joints, the edges prepared remains intact, only the filler metal is brought to the molten state and the melting of the faying surfaces does not take place.

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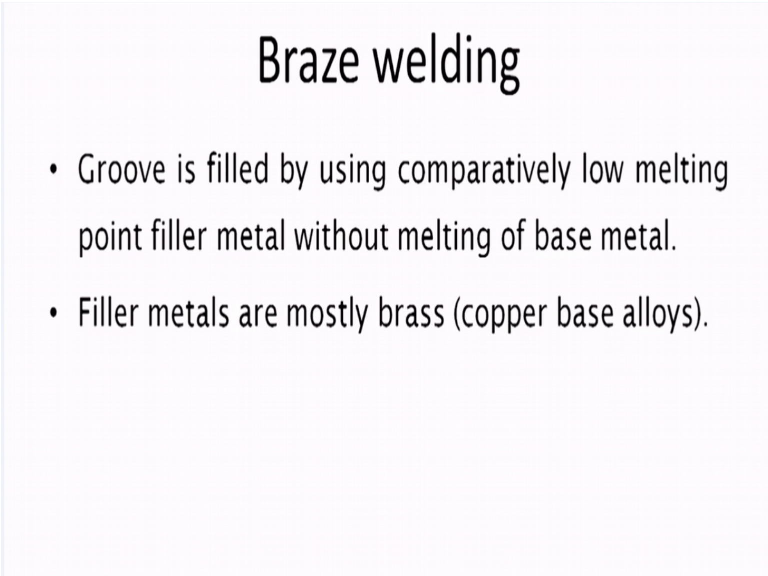

So in this case, first the groove weld is filled using comparatively low melting point filler without melting the base metal and fillers are mostly used as a brass that is copper base alloy. The braze welding is primarily used for joining the very difficult weld metals like cast iron and high carbon steels or also for repair of the cracks because the brass offers reasonably good strength and if the cracks have been developed it can easily repair them for the different functional purposes.

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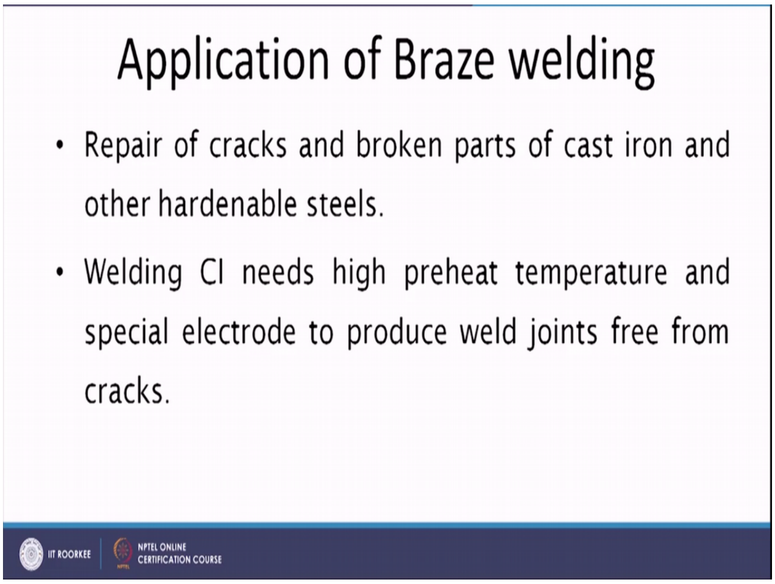

In case of the cast iron, if the repair work is needed then preheating is required to avoid further cracking tendency.

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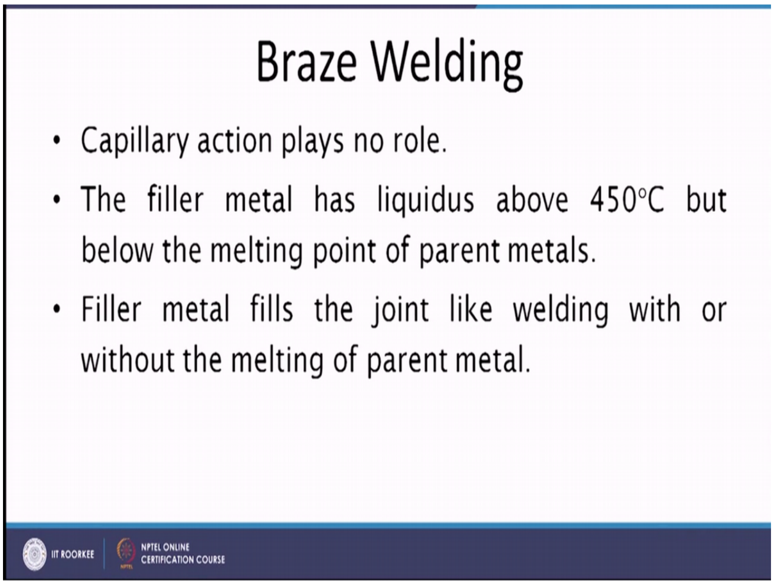

So this is what will see the further details related to the braze welding. No capillary action, capillary action does not play any role and filler metal has a liquidus above 450, but below the melting point of the base metals and the filler metal fills the joint like the welding with or without melting of the faying surfaces

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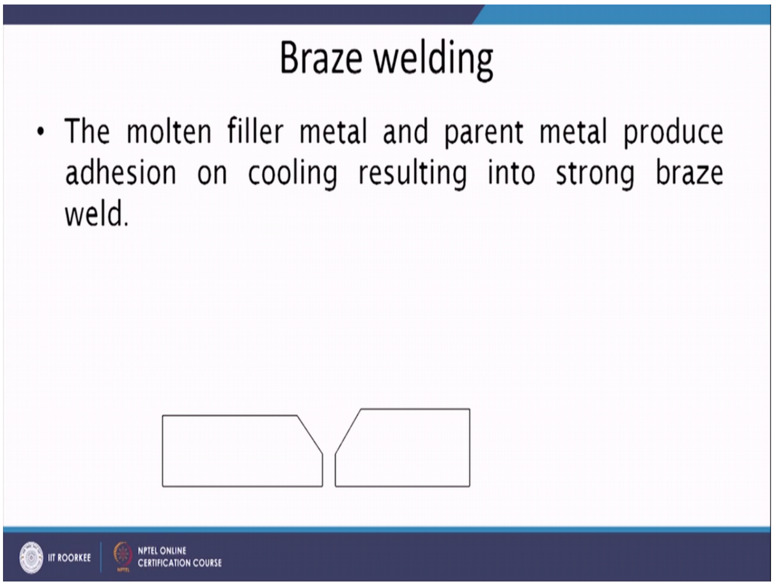

So melting of the faying surfaces hardly takes place and the molten filler metal and the parent metal produce the joint by adhesion on cooling result in the strong braze weld.

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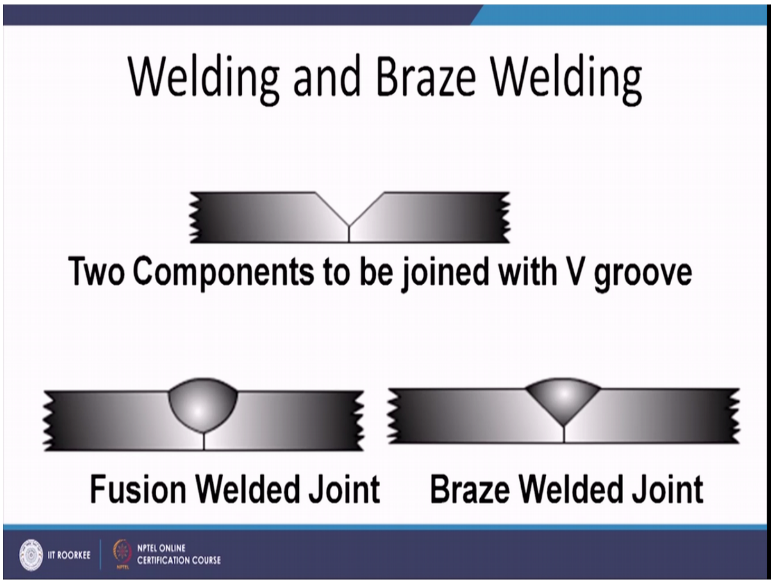

This is what I have explained like initially if the edges are prepared like this for developing the joint in case of the fusion weld, the faying surfaces are melted and we get the typically curved geometry of the fusion boundary. Well, in this case there is no fusion of the faying surfaces so the faying surfaces remain straight, the edges remains straight, only the gap is filled in by the brazing material. So this how we can easily distinguish between the fusion welds and the braze welds.

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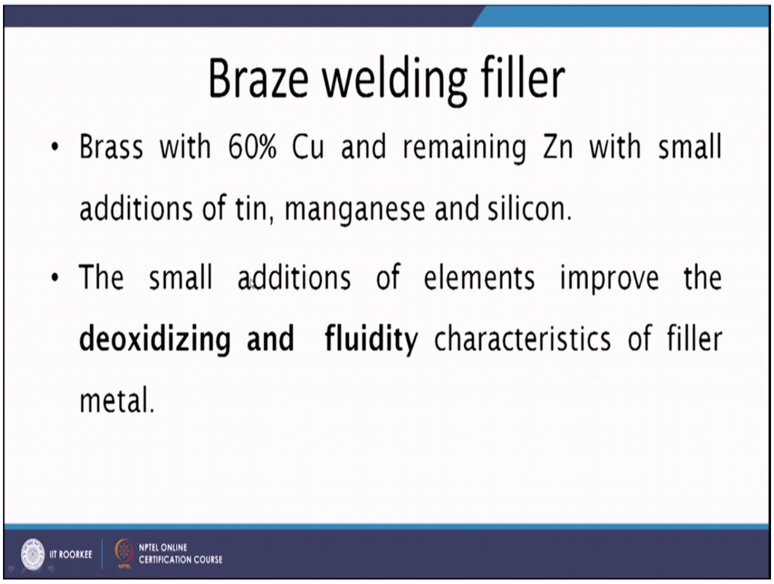

The brazing filler mostly 60% copper, it is a brass with the remaining zinc amount while small amount of the other alloying elements like tin, manganese and silicon are added for achieving the specific functions like deoxidization and improving the fluidity of the filler so that it spreads in course of the braze welding process and it occupies the different gaps whatever ups and downs expertise peaks and valleys are present on the surface of the material.

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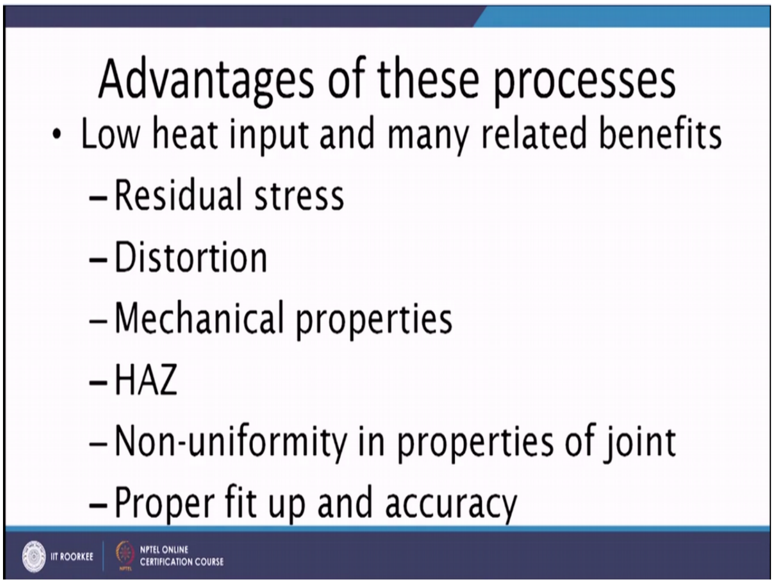

So if we compare the solid-liquid process as compared the fusion weld processes, we will see that the solid-liquid processes offer the low heat input and since these processes are low heat input because there is no fusion of the base metal, there is no fusion of the faying surfaces that is why since these are of the low heat input processes that results in the very low residual stress.

Because the volume of the metal, which is heated and subsequently cooled during these processes like soldering or brazing is very small.

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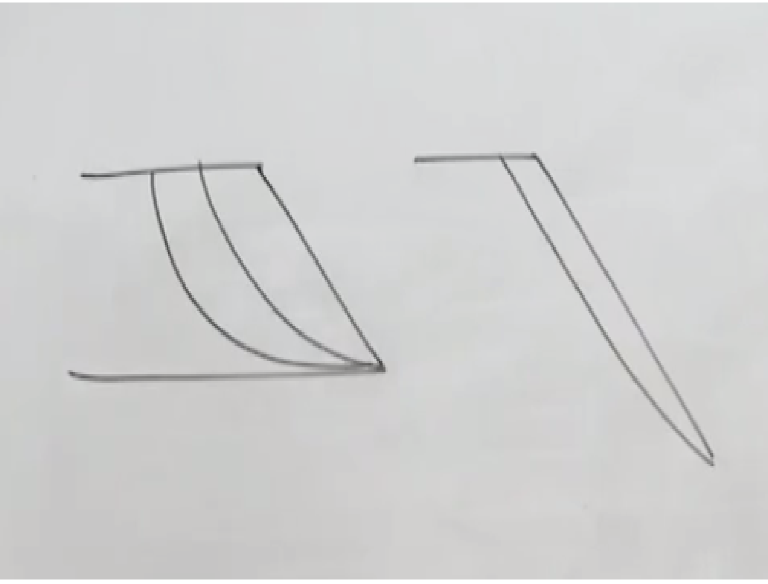

The extent of heating and the volume, which is heated that is very limited. In case of the fusion welding, it is very large and heating results in melting in case of the fusion, but in case of the soldering it just heated up to certain temperature like say 400, 500 or 800 degree centigrade. Fusion is not achieved in case of these solid-liquid base processes.

So the limited heat input results in the limited means small the volume of the metal, which is heated and subsequently cooled during the process is very less and that is why residual stress tendency is very less. In these cases, the distortion is also less because this is coupled with the residual stresses. Mechanical properties are reasonably good. It is not so in case of the soldering, but the brazing and braze welds offer reasonably good joint strength for the moderate application, moderate load conditions, heat affected zone due to the low heat input.

In any case, the heat affected zone size is very limited and even non uniformity properties in the joints. In this case, whatever the joint is there, within that the properties are uniform, but as soon as we come across the base metal certainly there will be large change in the properties of the joint and proper fit up and accuracy is possible because we can preset the things to be joined and then they will not be brought to the molten state, there will not be many dimensional changes due to the heating and cooling that is why the proper fit up and accuracy can be achieved.

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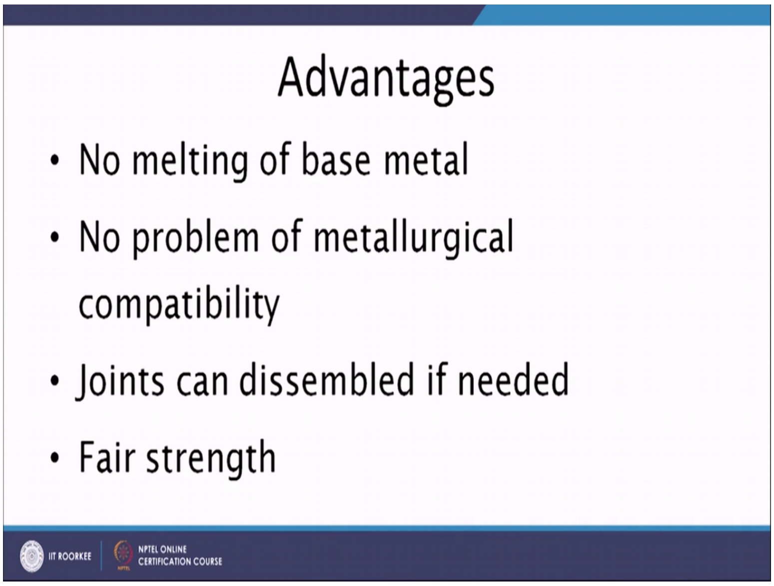

Additionally, there is no melting of the base metal, no problems with the metallurgical compatibility and if required then joints being weaker than the base metal, so the joints can be broken if the assembly is required and the joint is off the fair strength. So this is what can be used since the joints are weaker than the base metal so they can be dissembled if required and for moderate applications moderate and load conditions, the joint is of the fair strength.

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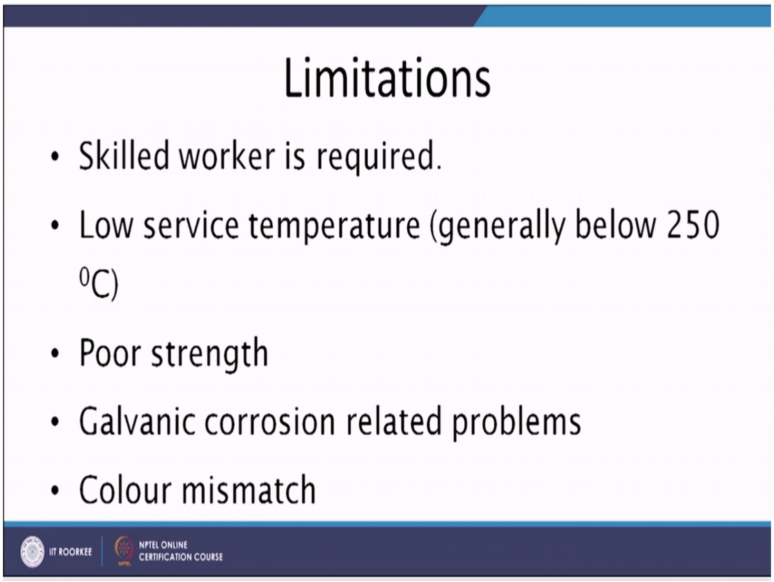

Limitations like skilled worker is required for applying, the temperature conditions for which the joints can be used is low like below 250 degree centigrade, certainly not solders can be used that high, but the braze welds and brazing joints can be used below 250 degree centigrade, strength is somewhat poor and due to the dissimilarity of the metals, the galvanic couple formation can take place, which can increase the corrosion tendency of the base metal as well.

And sometimes the steam value is also lost because the copper or the solder braze or the solder may have a different color from the base metal. So the color mismatch problems can also be there in case of braze and the solder joints. So now I will summarize this presentation. In this presentation, I have talked about the factors that govern spread-ability in case of the soldering and the factors that determine the strength of the joint in case of the solder apart from the principle of the braze welding process, its applications, advantages and limitations. Thank you for your attention.