**Joining Technologies of Commercial Importance**
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**Lecture - 22**
**Weld Bonding**

Hello, I welcome you all in this presentation on the weld bonding and this presentation is related with the subject Joining Technologies for the Metals.

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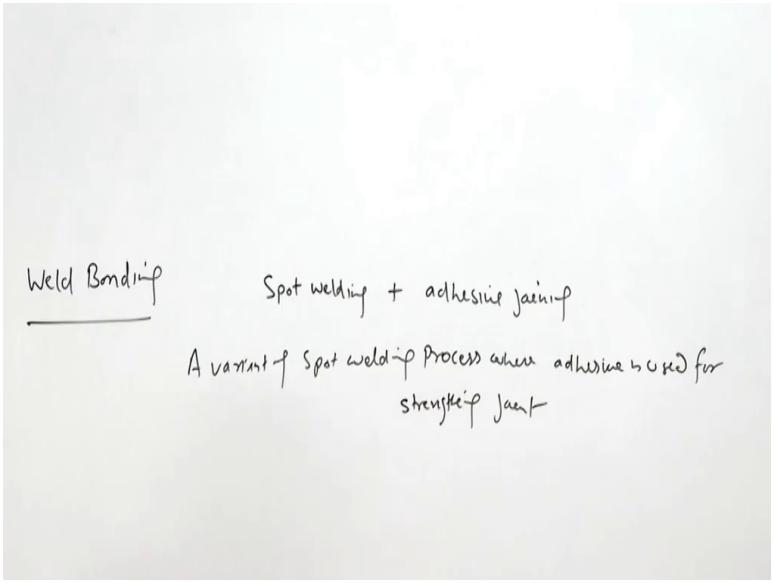


So the one technique called weld bonding is used for joining of the metals if you will see this process is a combination of the two processes, one is spot welding and another is adhesive joining, so this is and this process is also termed as a variant of spot welding process where adhesive is used for strengthening - strengthening the joint, so basically the joint produced by the spot weld is further strengthened with the use of adhesives.

We will see the details of this process combining the two processes.

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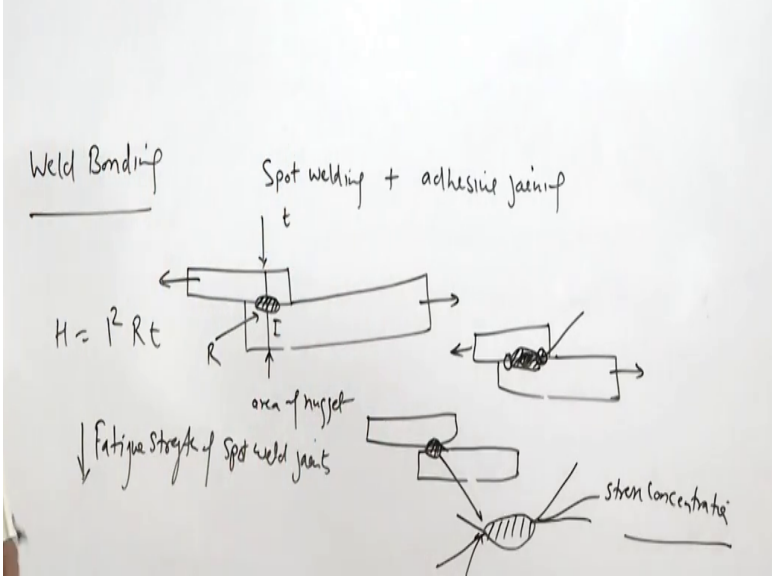


We know the typically spot welds - spot welding is used for producing the lap joints like this by supplying the high current through the contact interfaces high contact resistance at the interface develops heat and this is how pressure is applied and current flows through the interface current I is allowed to flow for the time t and contact resistance at the interface R helps to develop the heat through I square R t heating.

And this in turn generates the this in turn produces the heat generated produces the weld nugget, so strength of the like shear strength or the tensile shear strength load carrying capacity of the spot weld in this case is governed by the area of nugget produced, so if the area of the nugget like say this lap joint if the area of nugget is small then load carrying capacity is limited as compared to the case when the weld nugget area is increased because it increases the shear area.

So more shear load is required for sharing the joint, so the tensile shear load carrying capacity of the weld nugget increases, but in this configuration typically if you will see the joint configuration than one plate will be coming like this on another plate comes like this and here due to the melting and then consolidation nugget is produced the junction between these two plates has very low angle connection like this.

So this kind of the connection two sides from the two sides here we have nugget if we see in enlarged form then you will get it like this, so here the stress concentration at the edges were the

two plates meet is found to be high, so stress concentration is high at the junction of the two plates in both the sides, while the nugget provides the metallic connection between the sheets being joint and this provides the required shear strength to the joint.

But the presence of this stress raiser due to the joint configuration possess lot of problems especially the fatigue strength - fatigue strength of the spot weld joints is found to be very low why because of the high stress concentration that exist at the faying surfaces or at the joint level where the two plates meet each other, so under this condition since the stress conc - high stress concentration exists at this location.

So under the fatigue load conditions the cracks easily initiate at this points and then they propagate, so the fatigue strength and fatigue life of the spot weld joints is found to be poor and therefore lot of efforts have been made to enhance the fatigue load carrying capacity or the fatigue strength of the joint, one of the approaches here is the use of the adhesives - use of the adhesives in combination with the spot weld nugget.

So what is done in that case there are two approaches which are used for combining the - the two processes like a spot welding and the adhesive joining.

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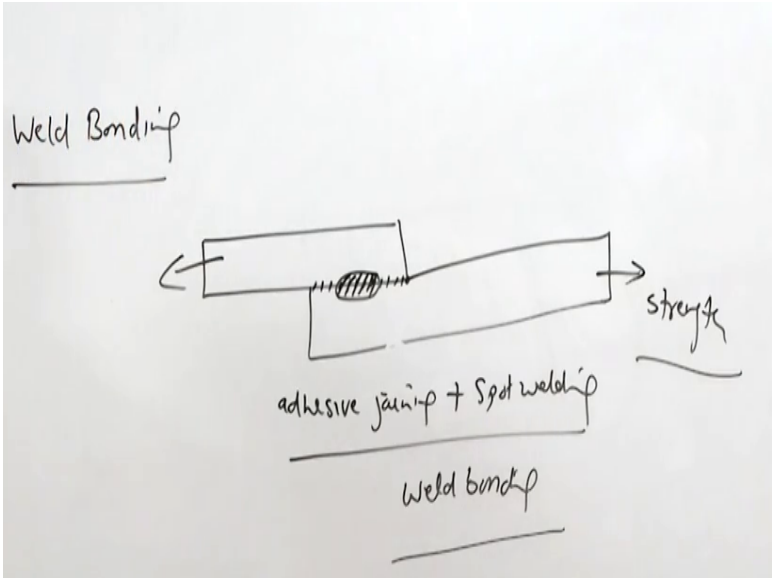

So typically what we get in weld bonding the structure comes out to be like this the orient - the joint configuration is same and first so in this case the adhesive joint is made between the - the sheets being joined this adhesive will be holding the plates together and in addition to the so it will provide some strength to the joint, so use of the adhesive will provide some shear strength to the joint which is further reinforced or enhanced with the use of the spot nugget spot weld nugget.

So when the spot weld nugget is developed it further it develops the metallic connection or the metallurgical continuity while earlier there was just adhesive connection through the adhesive joint, so this spot weld further increases the load carrying capacity of the joint, so this combination of the adhesive joining plus spot welding is called the weld bonding. So basically it is the combination of the adhesive joining.

And the spot welding which one will be, so how these - these weld bond is developed. There are two approaches which are used for developing the weld bonds.

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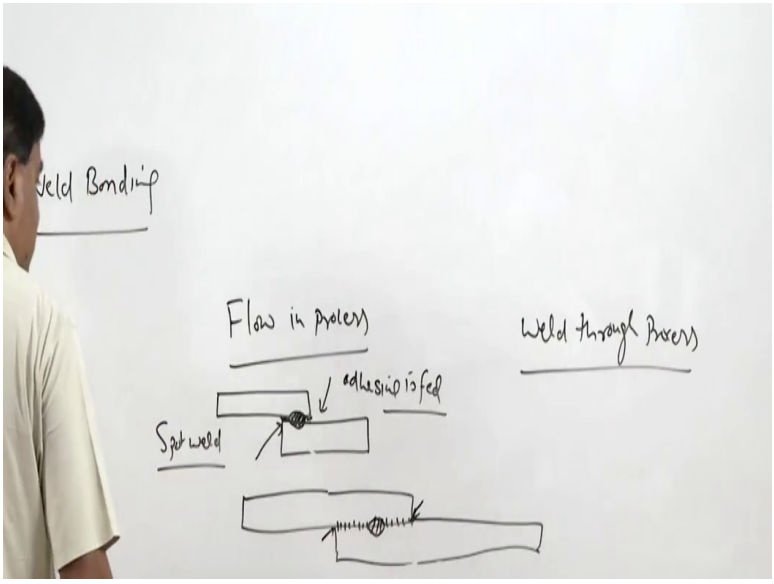


And the name of these approaches is like flow in process and another is weld through process, the basically the difference is in that it in which stage the adhesive is applied between the faying surfaces. so in flow in process what we do first the plates are taken or sheets are taken they are

put in faying in the required configuration and then spot weld is made, so first the spot weld is made.

And once the nugget is formed the adhesive is allowed to flow between the faying surfaces by the capillary action. So adhesive is fed between the - the sheets being joined so it gets its spread here and wets the surface so basically first what we do like this just for the sake of clarity what we can have the sheets in lap joint configuration spot is made first and then this gap is filled in with the adhesive so here adhesives will be spreading in the gap between the sheets.

So first we make spot weld and then adhesive is fed between the - the sheets being joined by the capillary action. So that it provides the adhesive joining in combination with the spot weld, so this is called flow in process where in first spot weld is made and there after adhesive is applied at the between the faying surfaces.

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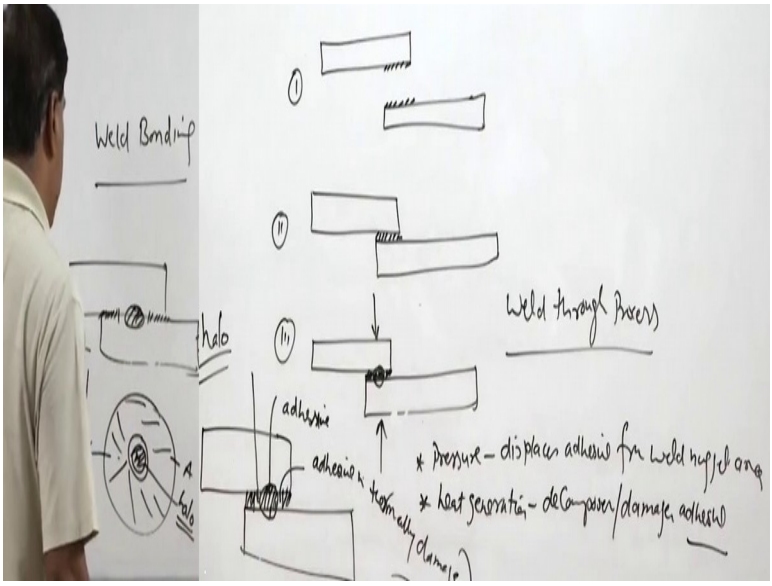


While in case of the weld through process in this case the first the adhesive is applied at the faying surfaces like this usually and then they are brought together like this, so here we have the plates in lap joint configuration with the adhesive, so the first step adhesive is applied then they are brought together in third step we develop the spot weld like this so when for during the spot welding when pressure is applied current flows it results in the two things.

One is due to pressure - pressure displaces the adhesives from weld nugget area first after that only weld nugget is formed and the second even if something is left and all around the weld market area heat generated - heat generated decomposers - decomposers or damages the adhesive all around the nugget adhesive present in vicinity of the weld nugget so damages the adhesive, so basically so there is one the adhesive is present here.

And when the spot weld is made adhesive is present in this area where a spot is being made is displaced and also thermally damaged, so there is very much possibility that the weld nugget may have these areas like one where our a adhesive is providing the strength to where we have welded nugget and this may have the adhesives as a inclusions burn adhesive in form of the inclusions and the pores and around that there will be a region where you will have the damaged adhesive in thermally - thermally damaged condition.

So whatever adhesive is there in thermally damaged conditions this region is known as halo wherein we have the adhesive but it is thermally damaged so thermally damaged adhesive will not be providing much strength definitely in this situation that there were two contributes contributors to the strength, one the weld nugget and the two adhesive which is still intact and providing the adhesive joining strength to the joint well.

But the area which is damaged thermally will not be providing the strength, so if we see the top view of this kind of joint what we will get this area where we have adhesive this is the area where we have nugget, this is the nugget area, this is where adhesive was applied and all around this there will be one area which will be thermally damaged this area is called halo where in the adhesive is damaged.

So these are the different factors, so as far as the - the factors that are contributing towards the strength that is this nugget which is providing the metallic connection and adhesive all around this you will be providing the adhesive strength, so relative so the total strength of the joint will be some of the strength due to the adhesive plus strength due to the nugget, some of these two will be determining the strength of the weld bond as a whole.

So relative size of the weld nugget and the adhesive joint area will be affecting the total strength of the weld bonds. So now we need to see the factors that affect the strength of the weld bonds, so since the process is a combination of the two this weld bonding is a combination of the two processes, so the factors related with the both processes will be affecting the strength of the joint.

So - so in flow through - in flow through in techniques technique what we have seen first adhesive is applied, adhesive joint is made and then a spot weld is made and once the spot weld made after that the joints are cured for achieving the required strength for - strength for achieving the desired strength of the weld bonds.

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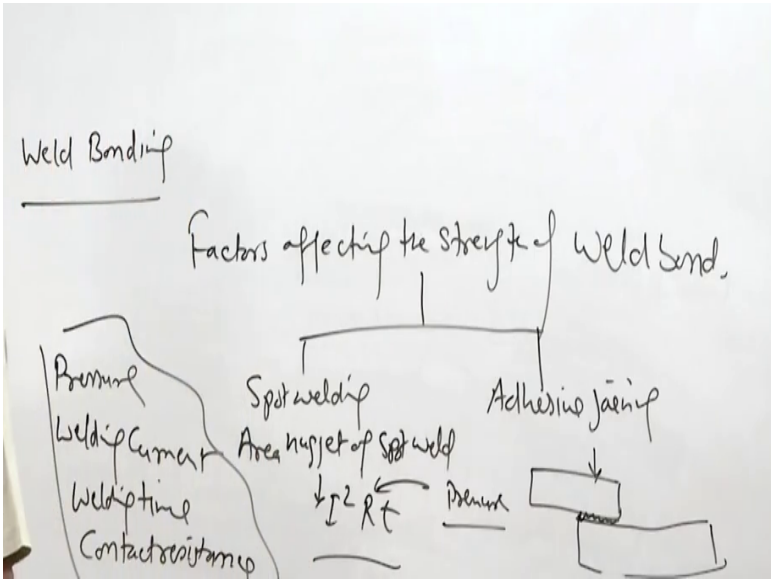


So as far as factors affecting the - factors affecting the strength of the weld bond we need to see both the processes. there are two processes, one is like say spot welding and another adhesive joining, so accordingly there will be factors associated with the both processes so strength of the spot weld is affected by basically the nugget area of - area of nugget of the spot weld and which in turn is governed by the kind of heat being generated which is I square R t.

So basically the three factors are there here one is the welding current, two is the - the welding time for which current is allowed to flow, three is the contact resistance and from the process point of view the both the surfaces the faying surfaces are kept under pressure so that arcing is

avoided and the consolidation can take place under pressure, so the third factor - fourth factor is pressure.

So all these factors affect the - the heat generation by the way of this I square R t increase in time, increases the heat generation, so increases the weld nugget area which in turn increases the strength of the weld bond also, similarly the increase in welding current, increases the heat generation, which in turn increases the weld nugget area and therefore the strength of the weld bond is also increased.

On the other hand, the pressure - the pressure directly affects the contact resistance say when the pressure is less there is a possibility of the arcing but when the pressure is sufficient so arcing is avoided but the contact resistance is high enough but if the for the pressure is increased that too much closeness between the expertise will be reducing the contact resistance which in turn will be reducing the heat generation.

Therefore, to match with the loss of the contact resistance reduction in contact resistance due to increase of pressure we must increase either current or the time for having the similar kind of the heat generation, so the weld nugget of the same area is made, otherwise increase in pressure increase in pressure can reduce the weld nugget area which in turn will be compromising with the strength of the weld bond.

So this is how the three the factors related with the spot welding will be affecting to the weld bond strength.

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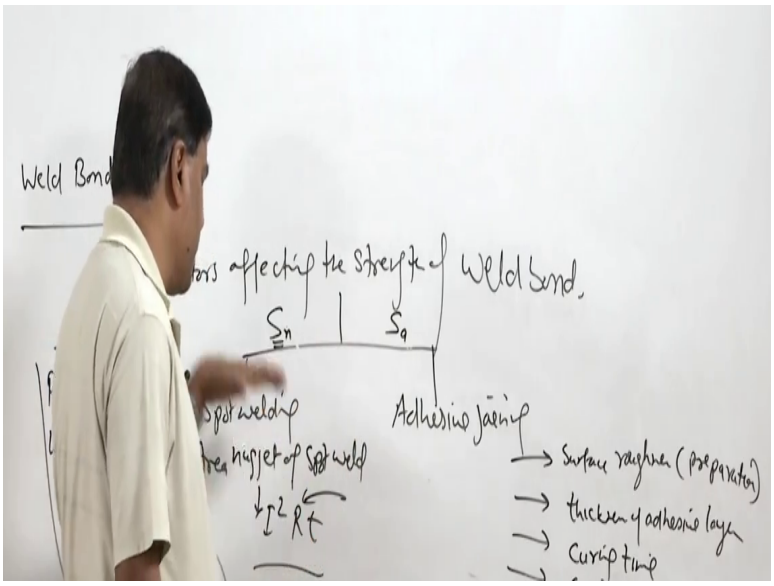


Since the process is a combination of the spot welding and adhesive joining? So say strength contribution from the spot welding is coming from the weld nugget and the strength contribution coming from the adhesive is so strength of the adhesive joint is affected by the certain factors these are like the surface roughness it is part of surface preparation basically preparation. The second is the kind of thickness of the adhesive layer.

And the two factors are basically related with the curing time and curing temperature so effect of all these factors will be seeing, now we have seen that increase in current, increase in time, increase in weld nugget areas which in turn will be increasing the bond strength similarly, increase in pressure reduces the contact resistance. So that may decrease under the identical conditions of the current and time.

It may decrease the weld nugget area so it may adversely affect the bond strength, but there has to be an optimum pressure so that arcing at the faying surfaces and between the sheet and the electrode can be avoided. Now we will see in detail how the adhesive joints the factors how the factors related with the adhesive joining will be affecting to the joint strength or the adhesive joint strength which in turn will be governing the strength of the weld bond as a whole.

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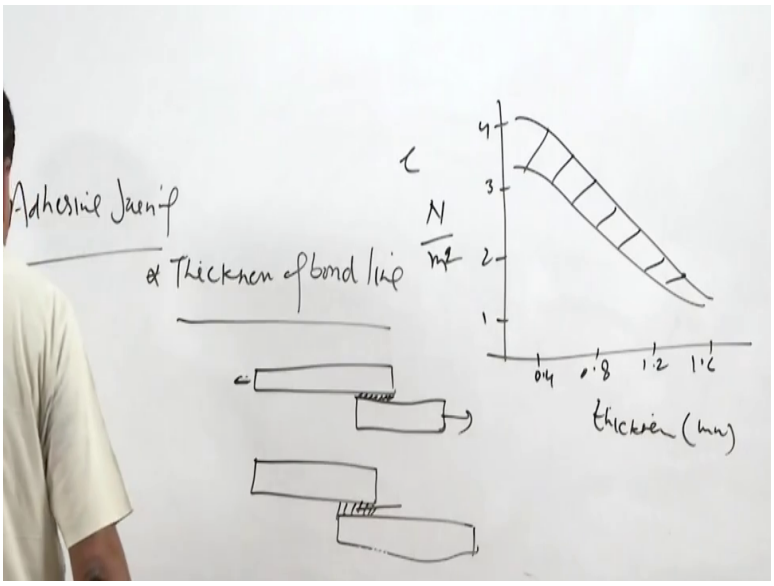


So as far as - as far as this one is concerned we will see the factors associated with the adhesive joining - adhesive joining first is say thickness of bond line or thickness of the adhesives, so what we can see here like this shear strength in newton per - shear strength in newton per meter square like say 1, 2, 3, 4 like this and the thickness of the adhesives in mm like say here 0.4, 0.8, 1.2, 1.6 in mm.

So what we will see that in general strength is maximum when thickness of the bond line is less goes in like this, so in general increase in thickness increases - increase in thickness decreases the shear strength load carrying capacity of the weld joint, so it is best when the thickness of the adhesive between the faying surfaces is minimum.

Because in this case the strength will be governed by the kind of bonding forces which are governing the strength of the joint they will be determining the strength of the - the adhesive joint as a whole, when the strength of the - when the thickness of the bond line is really more in that case failure of the adhesives takes place, so the adhesives in that case the force is determining the joint strength will not be very much responsible for this strength of the joint.

But the strength of the adhesive will be determining these will be determining the strength of the joints in this case you are when the thickness of the adhesive is more our the - the joint strength decreases with the increase in thickness so it is best to have the minimum possible thickness of

the one line when it is uniformly distributed over the entire surface area, basically there are - there are three mechanisms so that governed the strength of the joint in case of the adhesive joining.

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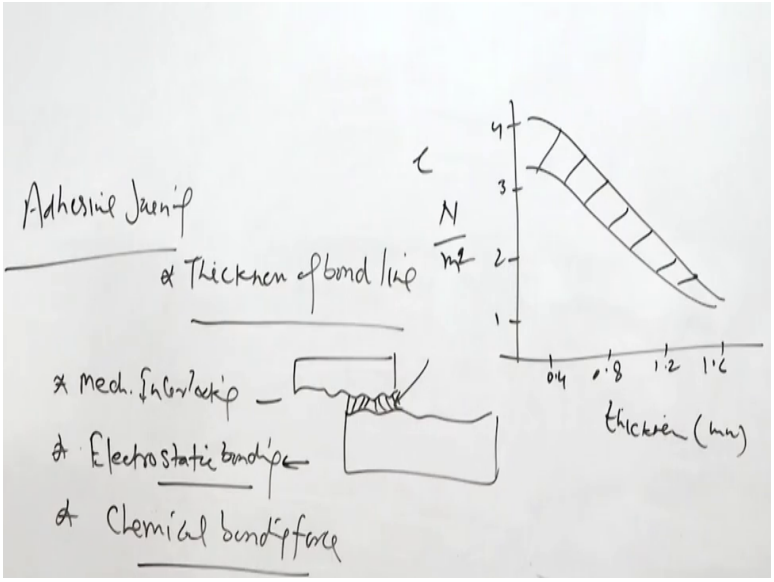


One is mechanical interlocking, two is the electrostatic bonding, three is the chemical bonding forces, so mechanical interlocking basically all the services have the regularities peaks and valleys at the surface when adhesive is applied it fills in the peaks and valleys of the - of the surfaces and thereby it provides the mechanical interlocking.

And electrostatic bonding depends upon the how different electro negativities of the adhering materials is there that in turn will be determining the electrostatic forces bonding and the kind of chemical interactions between the adhesive and the surface of the sheet is taking place they will be determining the - the bonding force all these three mechanisms maybe overlapping and in turn will be determining the for determination of the joint strength.

so as far as the bond line thickness is concerned this is - this is the effect of the thickness of the bond line or thickness of the adhesive layer over the surface - over the strength of the joint or shear strength of the joint.

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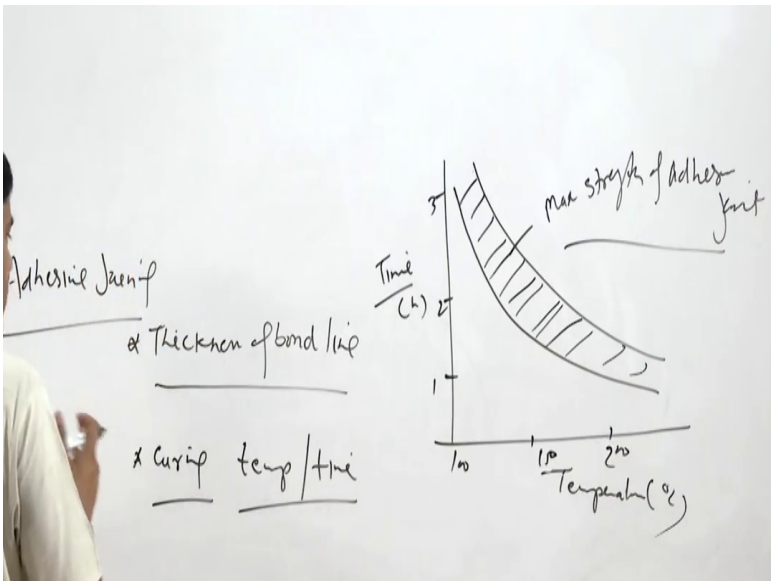


Second one is the - the curing aspect which includes the temperature as well as time, so if we will see the combination of the time and temperature for the curing in y axis if we have time in hours and in x-axis we have temperature in degree centigrade then what we will have like say 100 degree, 200 degree, 300 degree, I say 150 and 200 degree centigrade and in y axis we have 1, 2 and 3 hours.

Then our strength in general for the maximum strength you see the shaded area indicates the combination of the time and temperature for the maximum strength of adhesive joint during this the - the chemical interactions and the molecular bonding will be taking place during the curing and so it is required to have the optimum combination of the time and temperature during the curing so that maximum strength of the adhesive joint can be achieved.

So this shaded area indicates the kind of combination of the time and temperature required for the curing either side - either under curing over curing will be adversely affecting the strength of the joint.

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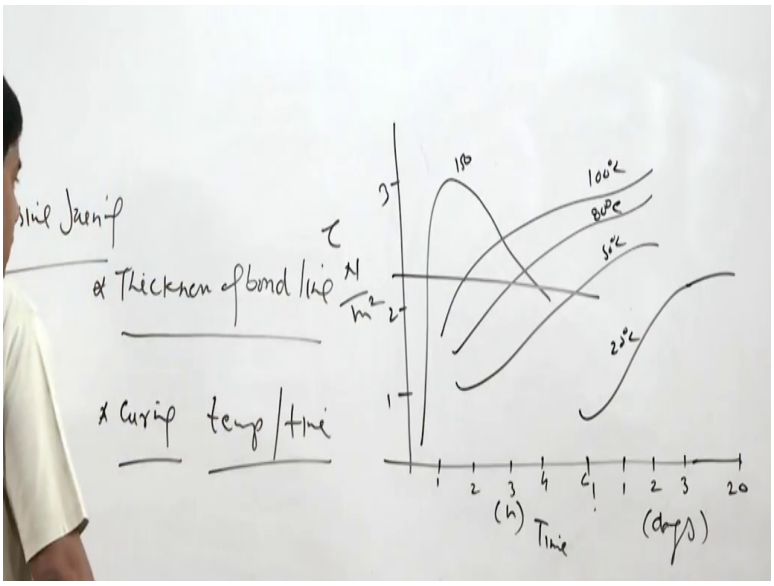


So now we will see one more diagram where we will be seeing the effect of the curing time and temperature on the shear strength of the joint, so shear strength of the joint in newton per meter square we will see here in y axis if we have time we will be using two scales basically just to show very long period of the time of the curing so here say it is 1, 2, 3 hours 4, 6 and then say 1, 2, 3 and here say 20.

So here this one here up to 6 we have time in hour. And thereafter time in days, it is like 1 day, 2 days up to 20 days. So what we will see that when we really work with the higher temperature in y axis we will have the same 1, 2, 3 governing the strength of the - shear strength of the adhesive bond, so here what we see basically the strength increases rapidly and thereafter starts falling when the curing is done at high temperature.

On the other hand, when curing increases, the strength rapidly when it is done at 100 degree centigrade. When it is done spread somewhat lowered say 80-degree centigrade curing again happens but it takes longer time for reaching the higher strength, this is for say 50 degree centigrade curing and then if we consider the curing at very low temperature than it may take very long time for achieving the peak strength say 20 degree centigrade.

So with the increase in temperature the time required for peak strength decreases it is very say 1 or 1 and half hours at 150 and then it keeps on increasing with the increase in temperature for

same strength, for example here at 100 degree centigrade we can get the same strength after 2 hours while at 80 degree centigrade its 3 hours and likewise, so at higher temperature of the curing that same strength can be achieved at shorter curing period.

So this is how we can say that the different factors associated with the weld bonding and adhesive joining will be affecting the shear strength of the joint. Now we will see the advantages and the limitations of the adhesive joints and the applications where these are used.

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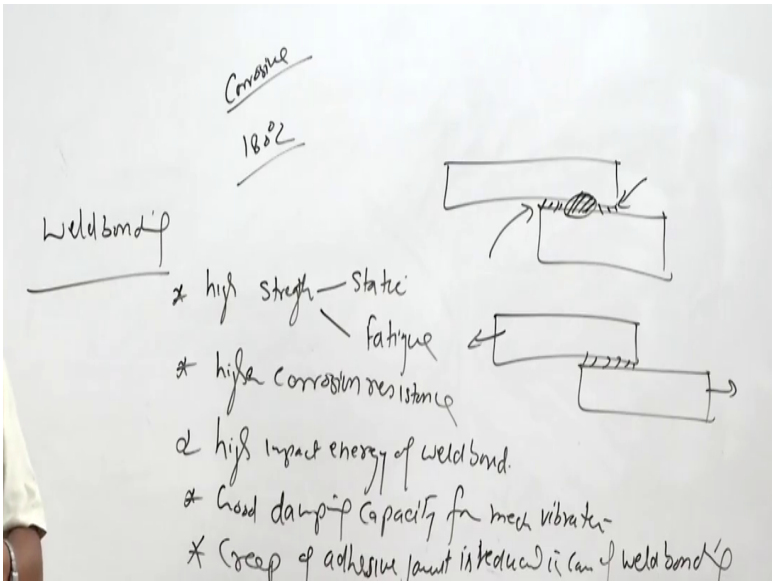


So here what we will see in case of the weld bonding, since the weld bonding is combination of the two processes so it overcomes the deficiencies of both the processes and provides much better strength to the joint so the - the weld bonding offers much higher strength - strength both static like tensile shear load carrying capacity or the dynamic or fatigue, so fatigue strength of the of the weld bond is found to be much higher than the spot welds.

So this is one major advantage of the weld bonding over the spot welding static strength as well as fatigue strength of the weld bond is found to be much higher than the spot welds, then we will see since the space between the sheets being joined is filled in by the adhesive, so it does not allow the entry of the corrosive media between the faying surfaces and thereby corrosion resistance is improved.

So it offers the higher corrosion resistance at the same time the - the - the combination of the metallic connection and the increased distribution of the stresses over a larger area of the adhesive joint combination of these two basically increase the energy required under the impact conditions, so high impact energy of the weld bonds as compared to the spot welds, so this is another benefit.

And the very good presence of the adhesive layer between the metallic sheets acts as a good damper, so the damping capacity - damping capacity of the weld bonds for mechanical vibrations is much better than the spot welds. So these are some of the advantages in addition to these we know that if we make just the adhesive joint then it shows the tendency to creep under the static load even under the static loading conditions means a little shift in the position of the - the sheets is observed even at the constant load, so that is termed as creep.

So that the creep of the adhesive - adhesive joint is reduced - is reduced in case of the weld bonds, so basically weld bonding reduces the - the creep of the adhesives that primarily is observed when the only adhesive is used for the purpose of developing the weld joints, so here these were some of the advantages of the weld bonding. Now we will see major limitation is that at high temperature - at high temperature the adhesive starts disintegrating.

So mostly say above 80 degree centigrade is adhesive will start disintegrating so this should not be used at high temperature, another in corrosive environment or in salt environment our adhesive may disintegrate or may decompose so that may further damage to the adhesive joint portion of the weld bonds, so this should not be used under those conditions. And very critical surface preparation is required to remove the all impurities from the surface.

And so that all decreasing impurities oxides, observed gases, moisture etc. from the faying surfaces of the sheets to be joined by the weld bonding must be removed, so it is critical to have this proper surface preparation - surface preparation. So these are the 3 or 4 the limitations we can say the negatives related with the adhesive are related to the weld bonding as for as the application of the weld bonding is concerned.

This is mainly used under the conditions where the joint is very critical and we want to reduce the stress concentration.

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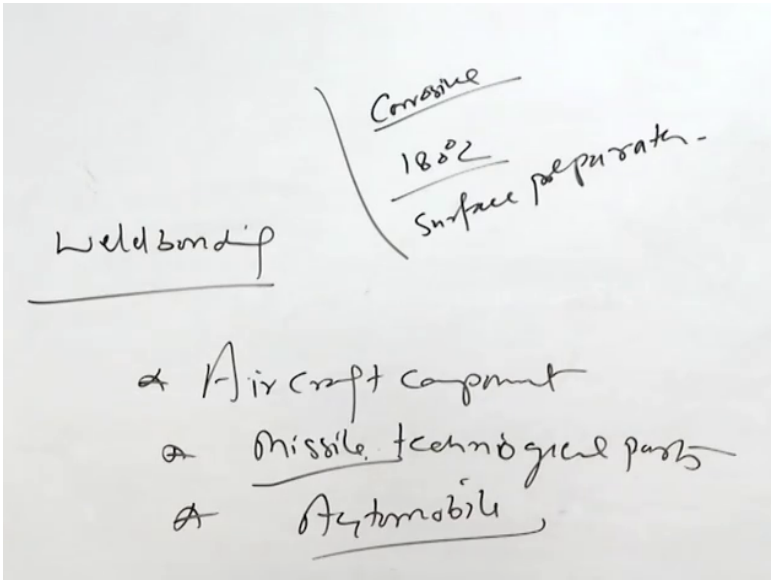


So mainly for joining of the aircraft components and in development of the missiles, joining of the missile technological parts, and also it is common in the automobile mobiles especially for the exports bikes and exports cars, these are used means the weld bonding is used which allows the much better the fatigue resistance as well as resistance to the corrosion. So now I will summarize this presentation.

In this presentation, I was talked about the weld bonding, the factors that affect the strength of the weld bonds and what are the advantages and the limitations of the weld bonds, thank you for your attention.