Manufacturing Guidelines of Production Design

Prof. Inderdeep Singh
Department of Mechanical and Industrial Engineering
Indian Institute of Technology-Roorkee

Lecture-27
Adhesive joining: Guidelines

Namaskar friends, welcome to session 27 of our course on manufacturing guidelines for product design. And as you were aware in the last week we have discussed about the various processes and the guidelines thereof. We have seen that for different processes, there are different types of guidelines or the design of the product that we must modify in order to make the process of manufacturing easier, effective, efficient as well as productive.

If you remember we have seen that design guidelines for machining, we have seen the design guidelines for parts to be made by powder processing, we have seen the design guidelines for parts to be made by extrusion injection-moulding, sand casting, die casting. So we have till now over the last maybe I must not say only the last week but last week last to last week. For example maybe in week number 4 and week number 5 we have seen various processes that can be used for making of various products.

And what are the modifications in the product design that we must carry out in order to ensure that the product is made easily. And in this week that is week number 6 we started our discussion about the joining processes because many times the product complexity, the product intricacy will ensure that the product will not be made in a single go or a near nut shape. The intricacy in the product design, the complexity in the geometry of the product will have to be taken into account by the product designer.

And the product has to be designed in such a way that it is made in 4 or 3 or 2 different parts which need to be assembled together to get the final product. And that is what we have already discussed in session number 26 and we have seen the different types of processes also. We have seen that for assembly operations we can either go for adhesive joining, we can go for mechanical fastening or we can go for welding of the 2 adherents or the 2 mating parts together.

For each of these we have seen what are the advantages, what are the applications, today we are going to talk about as is clear from your screen that we are going to talk about the adhesive joining. And what are the guidelines that we must keep in mind when the product has to be assembled using the adhesive joining process which means the product design is such that it will be made in 3 or 4 different parts and these parts will be assembled together.

And which process is going to be use the process of adhesive joining is going to be use, now we have to see that how the joints must be designed, what are the guidelines for these joints, what type of stresses are going to come on the joints when the product is going to be use. And how to avoid these stresses, what are the best type of joint designs that we must use. So all that we are going to discuss today, what is adhesive joining, we are not going to discuss maybe in detail.

Because there are various MOOC's courses, various books in which this information is already available. But the kind of information we want to discuss it is also available in the books on the internet but not available in a complied form, for maybe on a good book on joining you can get all these guidelines. On a good book on machining you can get guidelines for the machining, in good book on casting you may get the guidelines for casting.

But here we are trying to combine the various guidelines under single umbrella, so that a designer may have a comprehensive source at his disposal or her disposal which he or she can use while designing a product for understanding the various types of guidelines. Now let us quickly start regarding adhesive joining maybe their maybe few learners who are only attending to this session, maybe many times there are learners who have registered for the course who are attending each and every session.

But there maybe learners who are stand alone learners just getting this single piece of information or the single discussion or single video lecture. So, for those let us just quickly rehears or revise what we have already covered.

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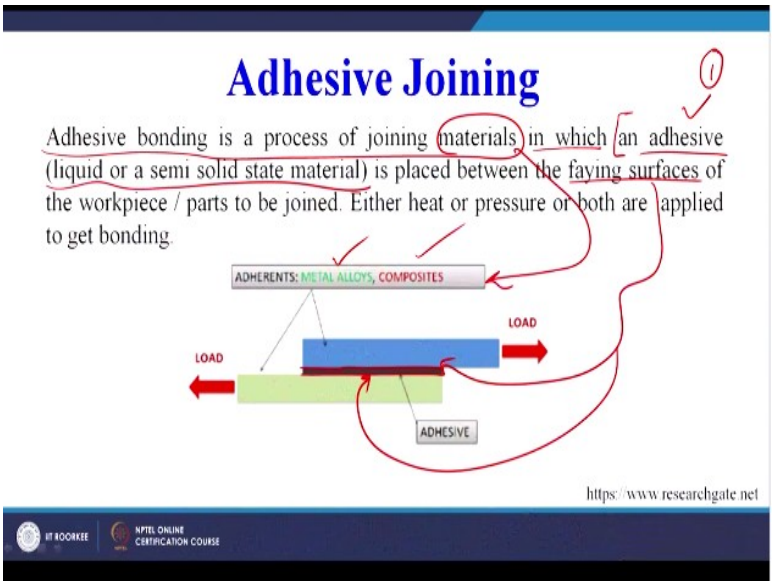

Adhesive joining is a process of joining materials the materials which are already mentioned here we can see the materials can be metals, alloys, composites, plastics, wood different types materials. So, adhesive joining is a process of joining material in which an adhesive which can be a liquid or a semi-solid material, this is adhesive 1K ingredient for ensuring the adhesive joining is placed between the faying surfaces.

Now what are the surfaces that have to be joined together, in this case this is a top surface blue color and the other one is the green surface. So, these are the 2 surfaces which have to be joined I will highlight them with the help of a line this is the 1 surface, this is the other surface that we have to join. So, an adhesive issues where is the adhesive, this black color layer which is shown here is the adhesive.

So, adhesive joining is the process of joining materials in which an adhesive is placed between the faying surfaces of the workpiece or the parts to be joined together, what are the parts to be joined together. This is part number 1 and this is part number 2, so these are the 2 parts to be joined together either heat or pressure. So, either heat or pressure or both maybe applied to get the bonding, so this is the bonding that we have achieved here between the 2 adherents, so this is the adhesive joining process.

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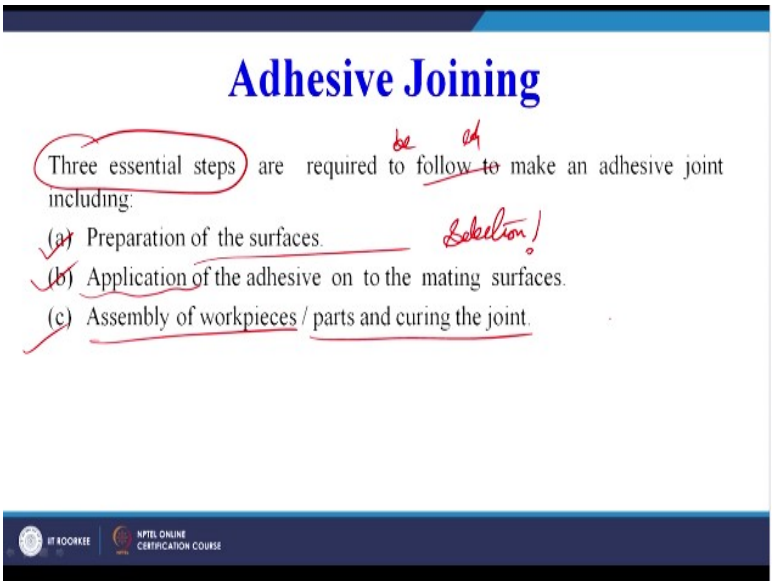

Now adhesive joining essentially requires 3 steps which also we have covered in the previous class. So, these are required to follow required maybe we can say to be followed to make an adhesive joint. Now these are the step involved first one is the preparation of the surfaces, so we have to see that the surface that we are going to join together must be adequately ready for making a joint.

If it is too having a too mirror like finish or having a too high value of surface finish it may not be able to join properly, if it is very rough surface again it will be difficult to join using adhesive. So, we have to ensure a proper surface preparation if the product has to be joined together using the adhesive joining process. So, for that we have to first prepare the surfaces to be joined using an adhesive.

The second is application of the adhesive on the mating surfaces, so second is we have to apply the adhesive and the choice of the adhesive also has to be done judiciously done intelligently, done logically. We cannot use all kind adhesives for all kinds of adherent materials or the materials to be joined together. So, we have to understand the compatibility of a particular type of adhesive for a particular type of surface or the part that has to be joined together.

So, that is the application of adhesive another point I must add here is the selection of the adhesive is also equally important. Once you have selected the adhesive properly then we have to

apply that adhesive on the 2 surfaces to make the bond. Third step is assembly of the workpieces parts and curing of the joints, so first thing is you prepare the surface then we apply the adhesive then you join the 2 parts together you may apply heat and pressure.

And then allow the polymer or the adhesive to cure to it is solid state and then you will get a permanent type of joint using the adhesive joining process. So, what are the design guidelines for adhesive joining that we need to understand.

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We can see here that adhesive bonds what are the advantages of adhesive bond that we have already discussed in the previous session, what are the application areas of the adhesive bonds, we have already covered. But here since we are using a adhesive bonding in our product and our design has to be modified accordingly to ensure that we are easily able to join the parts together using the adhesive bonding technique.

We have to understand at what type of loads, what type of stresses it can bear, so the adhesive bonds resist shear, tensile and compressive forces better than the cleavage or the peel, 2 examples of cleavage and peel are given here cleavage, peeling. So, these 2 type of loading environments are stresses or dangerous for the adhesive type of joints whereas the tensile stresses which are given here, shear stresses it is able to bear in a much better or in a much efficient manner.

So, the adhesive bonds resist means they are good against shear tensile and compressive stresses better than cleavage or peel design assembly. So, here we can see this is part number 1, this is part number 2 and there maybe a de-bonding between these 2 parts by the formation of a cleavage. So, that is a issue if that kind of non uniform loading or maybe unsymmetric type of loading is coming into picture cleavage and peel stresses may develop and lead to failure of the adhesive joint.

And here we can see in this direction the peeling action is taking place because of the load acting in this direction. So, this is the first adherent, this is a second adherent and this is the adhesive which has been used to make this joint. So, peel stresses are leading to failure of the joint by peeling action, so here the cleavage and the peel are dangerous from the adhesive joining point of view, tensile compressive and shear stresses the joints are able to bear in a much better manner.

The joints which have been made up the adhesive joining process, so the principle types of loading and countered in adhesive bonding with the actual applications. So, when a joint has been made by adhesive, so such types of loads may take place or such type of loading environment maybe there. So, we have to design our joint in such a way that it is able to bear all these types of stresses that are developed during in service of our product that we have designed.

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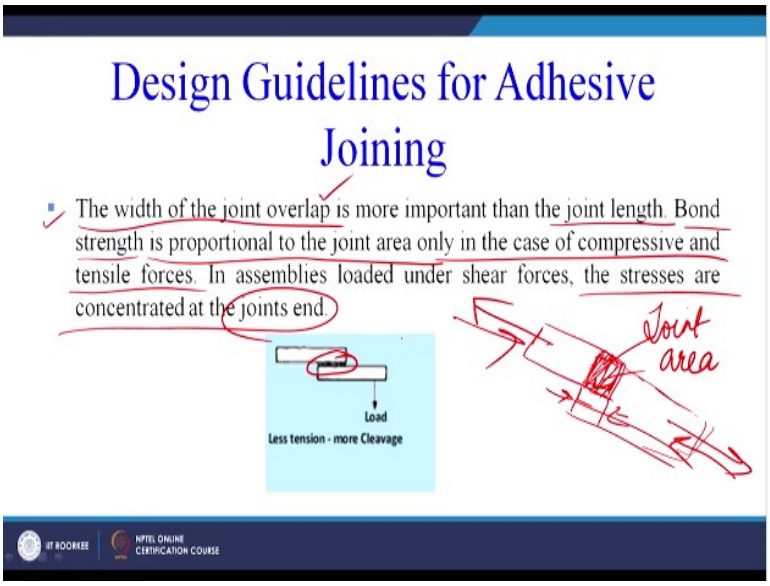

Now the width of the joint overlap, this is an important guideline, the previous one was that when we are designing the product we must ensure that what type of loading is going to come on the product. And if we are using the adhesive joining what type of loads it can bear or resist easily and what type of loading are detrimental to the performance of the product. So, we have seen peel and cleavage stresses are somehow going to be having an adverse effect on the product.

So, we must design the part in such a way that peeling off or the cleavages are not developed during the loading of the product or in service during the product usage. So, the second point is the width of the joint overlap, now this is the joint overlap area, the width of the joint overlap is more important than the joint length. So, the joint will have 2 important parameters, so if we can make a joint like this, so this is the length of the joint and maybe this can be the width of the joint.

So, we have this important as we have seen on the screen the width of the joint overlap is more important than the joint length. Bond strength is proportional to the joint area only in the case of compressive and tensile forces. So, this area we can see is going to affect if we can make it slightly like this, this area the overlap joint overlap area is going to affect the forces or this is going to affect the failure loads.

So, the bond strength or the failure load is proportional to the joint area only in the case of compressive and tensile forces. So, if it is being loaded in tension or it is being loaded under compression, so this joint area is going to affect the bond strength, in assemblies loaded under shear forces, the stresses are concentrated at the joint ends. So, depending upon the type of loading that is going to come on the product.

Now for example we can see that this type of product or this type of shape is going to be mostly loaded under tensile loading environment only. So, we can work on the joint overlap area or it is given here the joint area which is going to significantly affect the performance or the bond strength of the joint. Whereas if the product is going to be loaded under shear, so under shear the maximum we can say dangerous area will be at the edges.

So, in assemblies loaded under shear the stresses are concentrated at the joint end. So, we have to see that when we are designing a product that what type of forces are going to be developed or what type of forces are going to act on the product. And how this design of the joint is going to resist those type of forces without failure, what must the appropriate joint area which will be able to resist the tensile and the compressive forces, how the edges must be designed? or the ends must designed to resist the effect of the shear type of loading that is to come on the product.

So, as it is clear from this slide that for compressive and tensile type of loading the joint area can be optimized. Whereas in case of shear forces the stresses are concentrated at the joint ends, so the design of the end is also equally important. So, we can see here that the joint design is significantly going to influence the performance of the product.

And wherever the products have to assemble together we must be very careful about the type of joint that we are going to develop. Now another important consideration we have seen the joint area importance of joint area in defining a bond strength especially in case of tensile and compressive type of forces. We have also seen that the joint design is very important.

In the previous case we have seen that what type of stresses are developed tensile, compressive, shear, peel, cleavage which one is important, which one is going to have a detrimental effect.

How the joint areas going to affect the bond strength then the coefficient of thermal expansion is also equally important.

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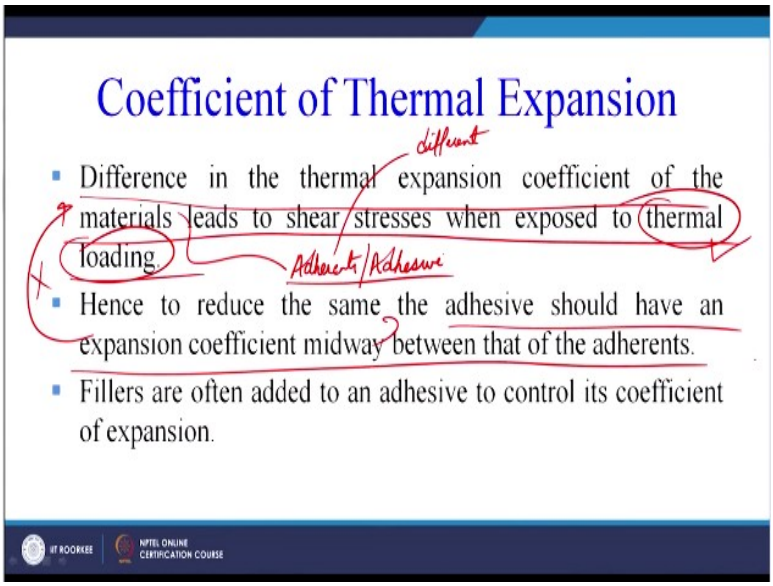

Difference in the thermal expansion coefficient of the materials lead to shear stresses when exposed to thermal loading. Now the different materials in this case maybe we can take an example of the adherents, so we have the adherents and we have the adhesive. So 2 different materials are there and in some cases the adherents may also be different, so your adherents are different your adhesive is a different material.

So, all 3 of them can have difference in the thermal expansion coefficient, so when heat is applied to the joint for example in a product it has to be subjected to a higher temperature or high heat input is there going into the product. And this joint is having a different material as 1 adherent another adherent is of different material and then the adhesive that is used is also different.

So, all 3 have different coefficient of thermal expansion, so therefore there is a probability of formation of the stresses which maybe shear stresses in nature. So, the thermal loading environment may affect the performance of our product where we are using adhesive joining technique. And therefore we need to overcome this problem during the design stages only, so hence to reduce the same.

So, this problem that is highlighted in point number 1 this we have to avoid how we can avoid. We can reduce this effect the adhesive should have an expansion coefficient midway between that of the adherent. So, we can choose the adhesive as I have told in the beginning of today's also that there are 3 stages for 3 steps to make adhesive joint, preparation of the surfaces, second is application of the adhesive and third one is consolidation by application of heat and pressure as well as curing of the adhesive.

So, the selection of the adhesive also is very important which I have emphasized there also. Here also because of the stresses that may develop because of the difference in the coefficient of thermal expansion of the adherents as well as of the adhesive. We must choose our adhesive judiciously and the adhesive should have an expansion coefficient midway between that of the adherent.

So, that we can nullify the effect of the shear stresses developed because of the thermal loading environment on our product. Fillers are often add it to an adhesive to control it is coefficient of expansion, so we can select adhesive with a proper thermal coefficient of expansion and we can add the filler also to control the coefficient of expansion of the adhesive. So, therefore this is also important guideline we must keep in mind when our product is going to have a number of adhesive bonded joint or adhesively bonded joint.

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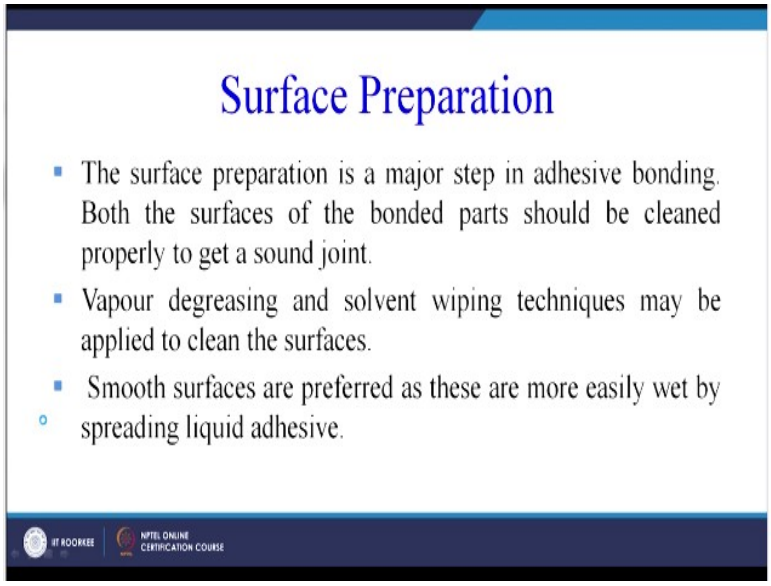

Now coming on to the surface preparation, the surface preparation is a major step in adhesive bonding. Both the surfaces of the bonding part should be cleaned properly to get a sound joint, vapour degreasing and solvent wiping techniques maybe applied to clean the surfaces. Smooth surfaces are preferred at these are most easily wet by the spreading of the liquid adhesive. So, this is just standard guidelines for ensuring a good joint efficiency when the joint is to be made by use of an adhesive.

But we must be very careful while preparation of the surface because the bonding has to take place between the 2 adherents and the adhesive. And in the previous session we have seen there are different types of failure mechanism when the adhesive joints are subjected to different types of load. So, we have to ensure that the joint that we make is having good bonding between the adherents and adhesive, so that can be ensured if we prepare our surface properly.

So, our surface must not be too rough it must not be too smooth, so we have to optimally select that what has to be the surface finish that is required to properly wet the surface of the adherent and form a good joint between the adherents.

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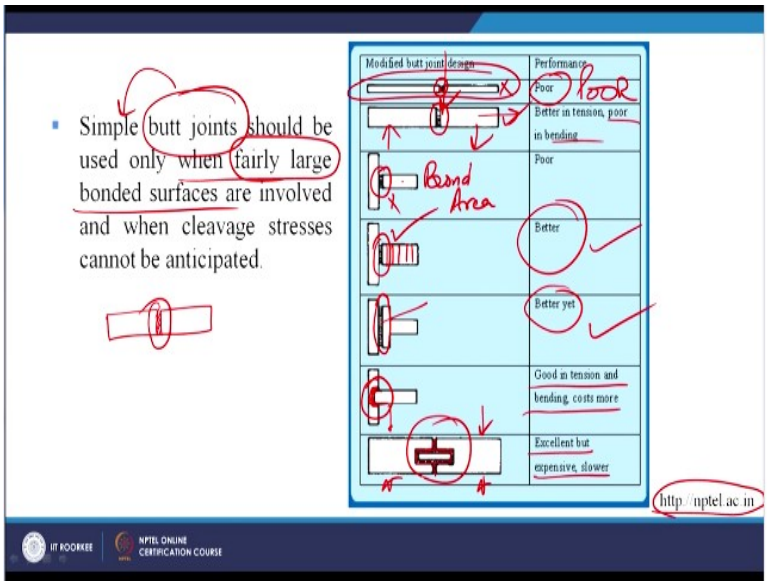

Now these are few guidelines which are already available on the NPTEL, so we can see simple butt joints should be used when fairly large bonded surfaces are involved and when cleavage stresses cannot be anticipated. So there are 3 things here the joint configuration is simple butt joint when we must use this butt joints when fairly large bonded surfaces as we have seen in the previous slide today only in case of a lap joint the overlap area or the bonded area is very very important specially in case of the tensile and the compressive type of stresses.

So in case of butt joint also, butt joint is as is given in the figure also this is a butt joint that we form here. So, the area that we are bonding with the help of the adhesive must be fairly large and when the cleavage stresses cannot be anticipated. So, we must have a fairly large area for forming a bond between the 2 adherents which have to be joint in the butt joint configuration, this is the butt joint configuration which is shown here.

So if we use our adhesive here and the area or the bonding area is less the performance will be poor as it is given on the screen. Whereas if you have a larger area this is certainly having larger bonding area as compare to this, so it is better in tension but it will be poor in bending. So, if you apply a bending load on this joint it may fail but if you apply the tensile loading it is better than the previous case, this is a poor design because the bond area is less here.

So, we have to ensure that the bonding area is significantly large, here this adherent you can see they here it is thicker one area is more as compare to this less area, more area. So, performance is better, it is even better you can see the increase in the bonding area here better**.** And here a joint configuration has been changed good in tension and bending but it will cost more, so this is another design which can be used and we can fill the adhesive here and form the joint.

And this is excellent from butt joint point of view but it is expensive and slower project will take time to make a joint configuration like this. And it is all dependent upon the bonding area as you see we have lot of area which we are bonding and the thickness is also large for the adherents. So basically we can see that there are different types of joint configurations possible if we use our creativity we can even come up with a better design as is shown here.

So the only thing is that we must keep in mind that we must design our joint in such a way that we have proper area available between the 2 adherents and the bond area significantly influences the performance of the product why because the product will be subjected to different types of loading. If it is a uniform type of loading it is easier for us to design the join but many time accidental loading may also come on the joint and that accidental loading may lead to failure of the joint that we have to understand.

And we have to make a joint in such a way that even in case of non symmetric or non uniform type of loading still with the joint performs better. So, this all easily related to the butt design of the butt joints wherever the adhesive bonding technique is going to be use. Wherever we are going to weld the metals 2 metals together welding being a different technique the joints will be of different type.

But here since adhesive has to be use for joining the 2 adherents together some of the joint configurations are shown here which can give us better joining experience and the product will perform better under different types of loading environments.

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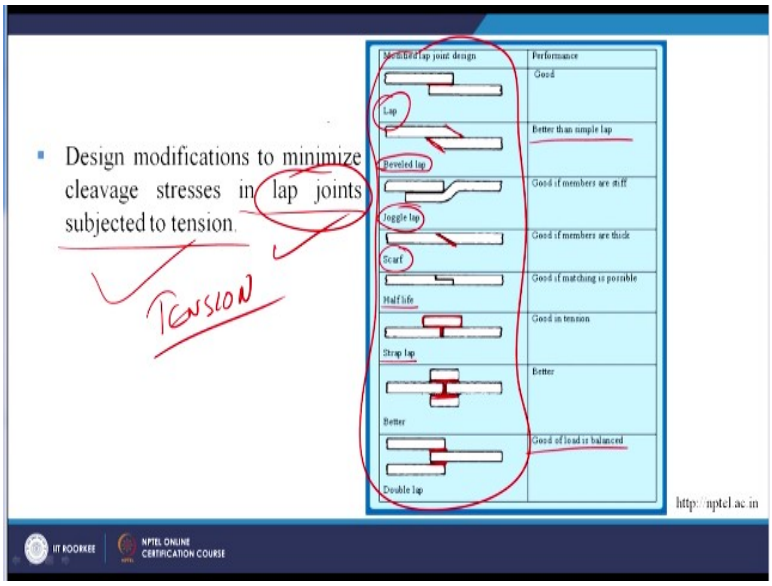

So, here we can see design modifications to minimize cleavage stresses in lap joint subjected to tension. So, here the joint configurations also fixed it is lap joint, the loading is also fixed which is tension. So, lap joints under tension what are the possibilities available with us when we have to make our product we have to ensure that the 2 parts which are going to be used in my product will be used under the lap joint configuration and the maximum loading will be under tension.

These are the types of lap joints that we can make use of, this is a single lap joint which is given it performance is good under tension. Then this is better than simple app we can see the edges have been modified here this is the beveled lap joint, this is simple lap joint, this is a joggle lap joint. Good if members are stiff this is scarf joint given here, this is half life joint, strap lap, this is the bonding area here and this is additional part that we are using good in tension.

It is still better, this is the adhesive which is being used and it is double lap joint, it is we are going to use the adhesive here good if the load is balanced. So, we can see the different types of lap joint configurations are also available with us when the product is going to be subjected to tensile type of loading. So when we are designing our product and we know that the loading maybe under tension or a tensile type of load may act.

We can design the lap joint using any of these configurations in order to get a product which will not sale even if accidentally tensile load x on the product.

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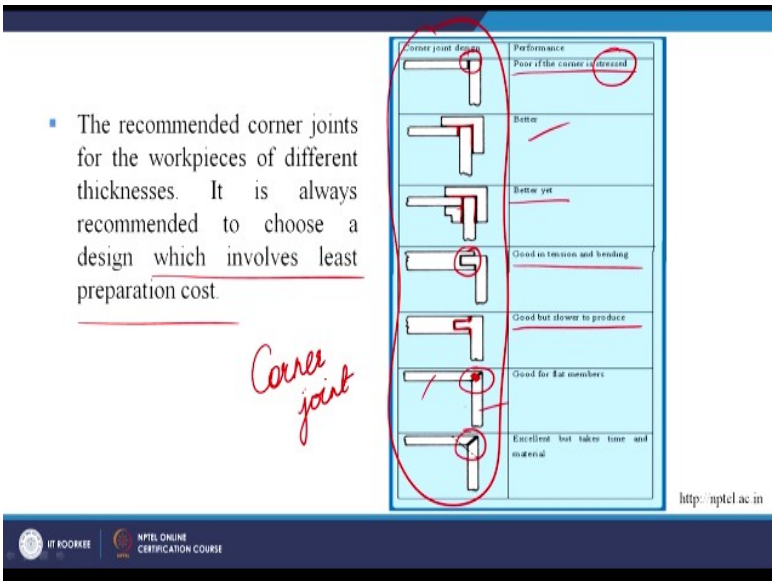

Now this is the recommended corner joints we can see 3 types of joint configurations we have seen. First one is related to the butt type of joint, second one is related to the lap type of joint and third one is related to the corner type of joint. So, the recommended corner joints for the workpieces of different thicknesses it is always recommended to choose a design which involves least preparation cost.

But we have to do trade off sometimes the joint maybe costly but it is performing better, so we have to do that kind of trade off when we are designing the product which have to be joined together using the adhesive joining technique. So, here we can see corner joint design it is performance is poor if the corner is stressed in case of stress at the corner performance will be poor this is better design better corner design.

This is even better good in tension and bending this type of joint we can make at the corner it is good in tension and bending. Good but slower to produce we can have this type of joint also, so this is another good for flat member if there are flat members we might have seen this type of joining of the flat, this is also flat, this is also flat. Then this is excellent but takes time and lot of material, so these are all the joining configurations where the corner joints have to be made.

So, when we are designing our product we must look at the various types of joint configurations which are available especially at the corner or maybe under the butt configuration or under the lap configuration. So all these joints must be there in our mind or even at least we must have this kind of information that this is available which we can take make use of or take advantage of. So, if we take advantage of these configuration we will be able to come up with a product which can bear different types of loading environments and will perform satisfactorily.

And will satisfy all the functions for which the product has been designed, so we have tried to understand today in this session that when we are going to use adhesive joining as a technique for assembly of our parts which are there in our product design. Those parts can easily be assembled using the adhesive joining technique subject to that we follow all these guidelines which are mentioned here.

We design our joints properly, we see the type of joint configuration that we have to use and also we take care of the difference in the coefficient of thermal expansion of the adhesives and the adherents. So, if we take care of all these guidelines certainly we will include the joints in our product which are going to be long lasting and are going to deliver as per the specifications of the product.

In next session we will have discussion on the other joining technique and what are the design guidelines thereof which we must keep in mind to ensure proper joining of the parts that are going to be assembled for making our product.
Thank you.