Manufacturing of Composites
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Lecture – 25
Repair of Composites

Lecture 25; today our lecture will be more focused towards repair of composites. So, when you talk about repair of composites our focus is more towards polymer matrix composites. So, there are several structures today which are made for load bearing usage. So, these structures over a period of time because of some damage which is getting introduced or the small imperfections which were there in the while fabricating a composite gets progressed over a period of time, so how do we repair these composites.

And as I told earlier also, thermoset composite is more popular as compared to thermoplast because it had a liquid as a starting material and the processing is easy and it gives good tailorability or it gives good draptability property to the required shape. So, these thermoset polymers have a problem of non biodegradability. So, whatever has got fabricated the lifespan has to be slightly enhanced for few more years before getting thrown off. So, people all across the world are working towards structural health monitoring of these composites.

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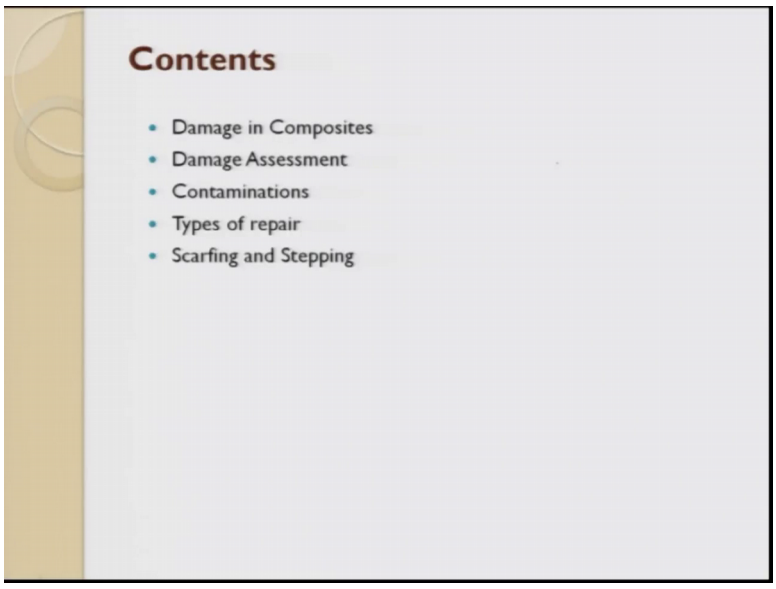

So, here in this lecture we will focus on if at all there is damage to a large extent how do we try to remove that damage or try to cover of that damage such that we enhance the longevity of their usage.

So, the content of this presentation is going to be damage in composites what are the different types of damages one; it can be on the surface 2, it can be in between; that means, to say a in the core and then start growing towards which is quite a common in sandwich structures. Then we will also have a for a tool we have to do is damage assessment because until and unless you detect a damage and assess the damaged, you cannot think of a remedial measure then the third one is going to be contaminates then types of different repair and the last one is scarfing and steppings which are involved in this damage.

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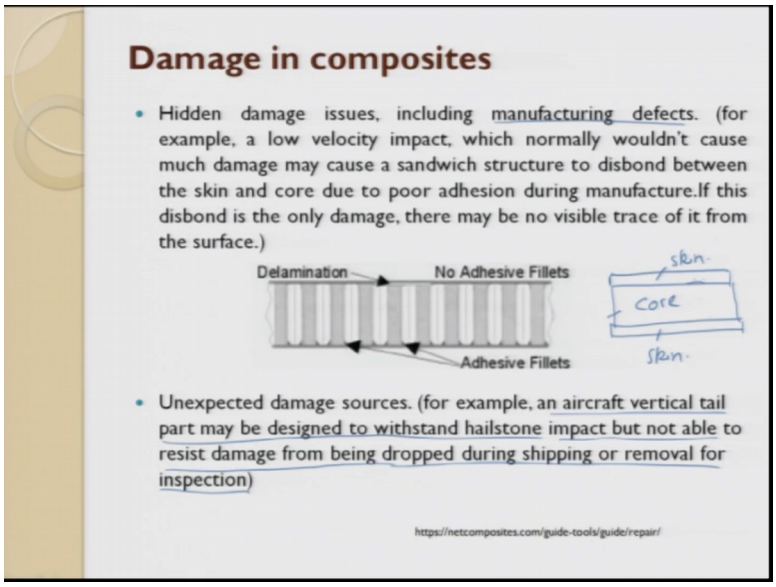

So, when we talk about damage in composites hidden damage is used including manufacturing defect which I was trying to tell; for example, a low velocity impact with a which normally would not cost much damage may cause sandwich structure to this bond between the skin and the core due to the poor adhesion during the manufacturing this; this bond becomes more common. So, generally in order to explain little bit more what are sandwich structures sandwich structures are structures where and which you have a softer core this is called as the core and this is called as the skin.

It follows the analogy of your high being. So, here this skin can be made out of glass fibre carbon fibre or Kevlar and they are just stuck on top of the core this core can be a honeycomb structure or it can be a ordinary foam which is which you put in between. So, generally what happens there has to be a stitching which is to be happening between the skin and the core. So, if this stitching is not done proper this leads to disbonding. So, when we talk about normal composites where we do not have the score this disbonding happens between the or de bonding happens between the layers between the lamellae.

But here what happens? It will happen in the top as well as the bottom it can happen and here all you have to do is if there is a small mismatch or if there is a small void between the skin and the core this leads to disbonding and if this for a sandwich structure even a small disbonding leads to a major reduction in the structural properties. See unexpected damage sources for example, an aircraft vertical tale part may be designed to which stand hailstone impact, but not been able to resist damage from being dropped during the shipping or removal for inspection. So, unexpected damages are for example, dropping of a spanner on top of a surface. So, this is an impact which happens on the surface of a composite. So, those damages are called as unexpected damage sources. So, you can have hidden damage and you can have unexpected damage.

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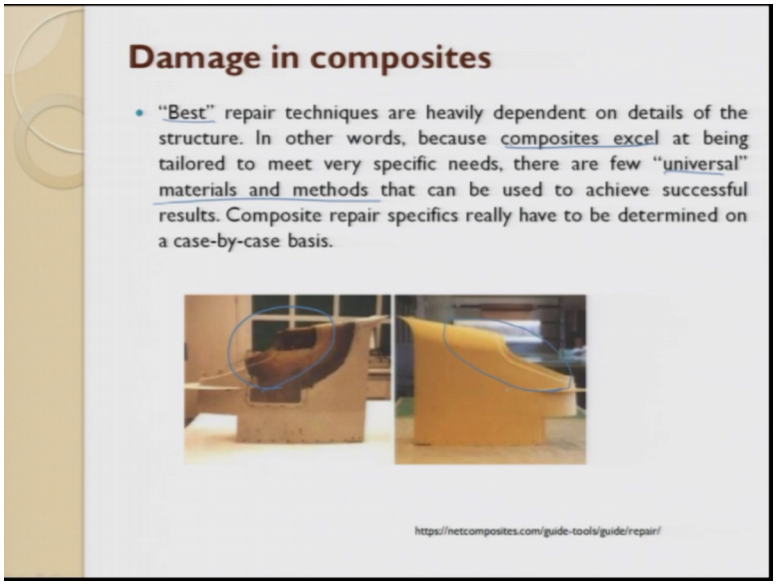

So, damage and composite the best repair technique are heavily depended on the details of the structure by knowing the structure knowing the load; what it comes knowing the

functionality, then only we can start thinking of remedial measures in other words because the composite excels as being tailored to meet the specific needs there are few universal materials and methods that can be used to achieve success full results.

However there has to be a case by case approach for dealing in correcting the damage in a composite. So, this is a damaged composite and this is the rectified composite you see here completely it is rectified. So, they have put a patch which is another composite of required orientation whatever it is and then they have been coloured; that means, to say they have been given a coating on the continuous coating.

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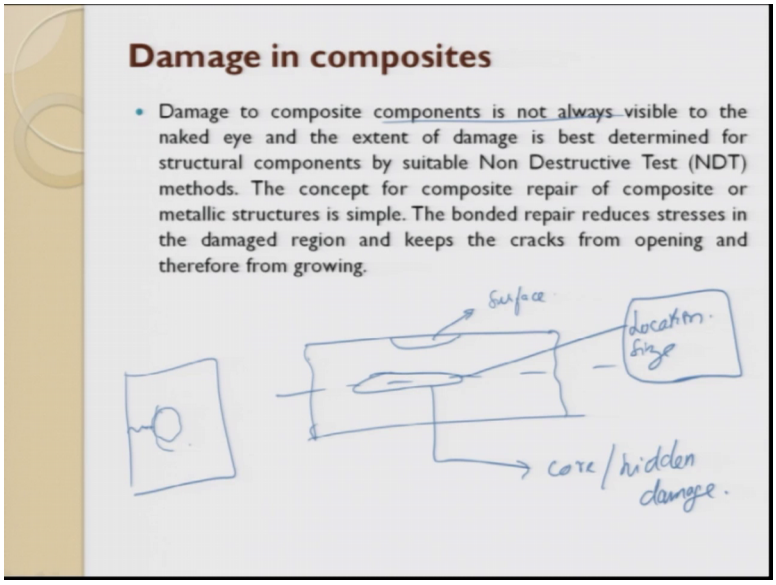

So, that it looks to be the same as the original part damage in composite component is not always visible by naked eyes. So, it can be on the surface the damage the if you take a composite the damage can be on the surface the damage can be on the core these damage are called as surface damage this damage are called as core damage or hidden damage core or hidden damage.

So, it is not possible to understand or find out the hidden damage through a naked eye. So, it is always required that we use some of the non destructive techniques to find out this for example, we have studied about the ultrasonics; we have studied about aqua STO optical ultrasonics all the things all these techniques are used to find out the location the location the size of the damage. So, first we have to access the damage and then only we should think of doing some remedial measures the concept for composite repair of

composites or the metallic structures is very simple the bonded repair reduces stresses; the damage region and keeps the crack from opening and therefore, from growing. So, what we do is we try to create went; for example, if you have a composite and if there is a crack which is growing. So, what you are trying to say is you try to make a hole. So, that this crack comes and hits at the hole and then distributes the energy such that that the crack does not further propagate.

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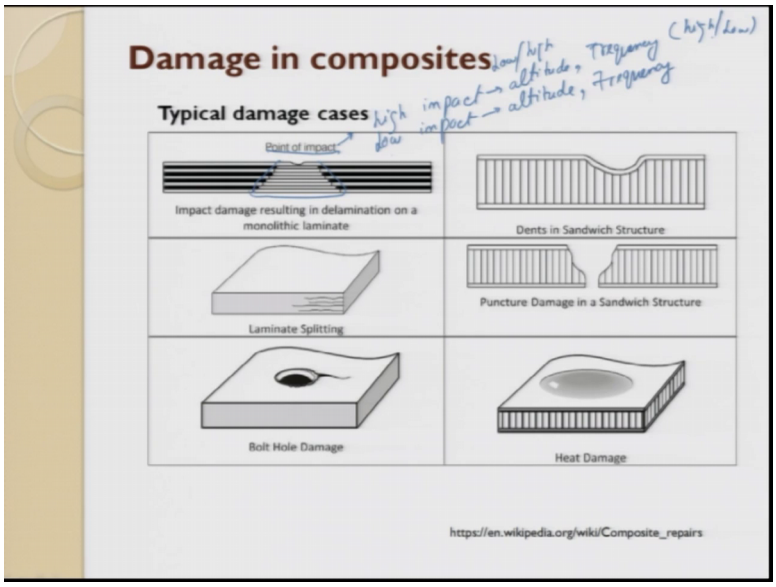

The bonded repair reduces the stresses in the damaged region and keeps the crack from opening and therefore, from growing. So, this is what is a crack opening happens and this crack is now bifurcated and the crack is not growing.

So, some of the typical damages are. So, because of the point of impact; generally what happens? The energy is getting dissipated in the composite like this. So, you will always have a damage which keeps growing towards the other side. So, here this point of impact can be a high impact or it can be a low impact low impact means small weights have been dropped high impact means heavy load is being dropped and then you can also have this altitude which is very important because we low impact low altitude means the height is small weight is small.

So, damage will be less low impact high altitude m g h. So, the kinetic potential energy will be m g h. So, h plays a very important role it will create a huge damage same way with high impact high impact low amplitude and then leaving this there is one more

parameter which is frequency you can have low frequency or high frequency. So, this can be high impact low slash high altitude frequency again can be high or low; that means, to say number of times the impact happens on a particular place.

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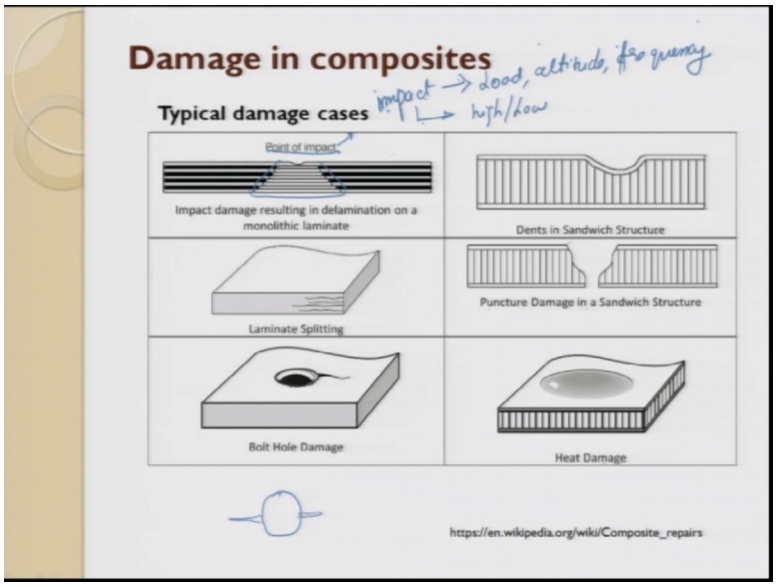

So, all these things play a very important role. So, it can be impact which is which depends on load altitude and it can depend on frequency and all these things can be high as well as low it can have multiple combinations to give this impact. So, this is on a monolithic laminate this impact point of impact is there. So, this is how the damage keeps growing the next one is dent in the sandwich structure. So, again this is a sandwich structure top and bottom skin and you have a core. So, this is a dent which happens.

The next one is laminate splitting maybe because of hygroscopic effect or the improper resin was there. So, low resin was there. So, these layers did not get stick stitched on properly. So, it is called as a laminate splitting which is there the next one is puncture damage in a sandwich structure again because of the impact loads it can be a bolt hole damage while drilling a hole, there is a crack which happens and this crack keeps growing generally when a hole is done there is a possibility the cracks will go in the lateral direction. So, this is a bolt hole damage and the other one is heat damage this is basically because of the heat getting applied to a sandwich structure the area the polymer resin gets heated and it forms a damage.

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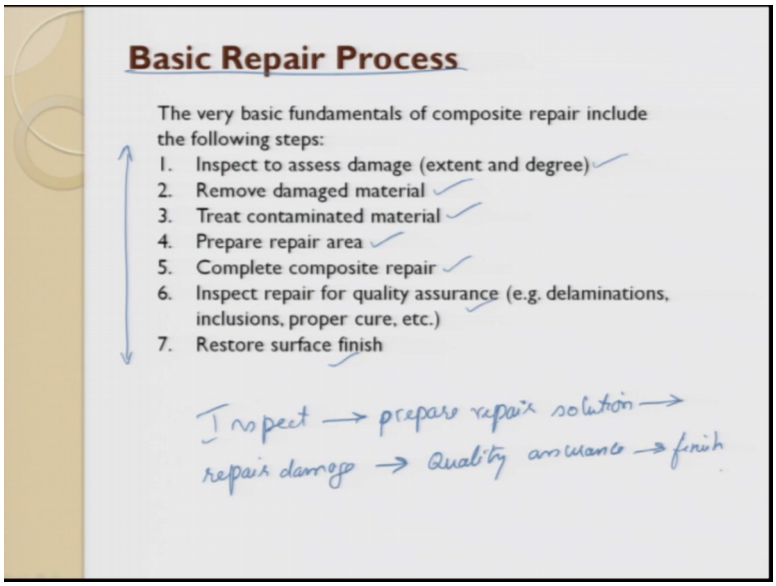

So, these are the different types of damage which are common in composites. So, what are the different basic repair processes? So, there are fundamental steps which are involved. So, the first step is to inspect and assess the damage next is remove the damaged material whatever was there, we gouge it out and remove it then treat the contaminated material.

So, whatever was removed and then at the joining interface, we try to do it, then prepare a repair area. So, generally the repair area is we try to gouge some amount of good material also. So, that we can try to have a uniform laying of it then complete the composite repair inspect for the quality assurance and then restore the surface finishes restore the surface finishes giving a very smooth layer. So, these are the steps which are involved. So, first if you see if you want to write it; it is inspect and then we try to make strategy or we try to prepare repair solution or solution or mat or whatever it is and then from there, what we do it; we try to repair the damage and then after repairing the damage we try to check for quality assurance and then we try to finish the composite whatever is to be repaired. So, these are the steps.

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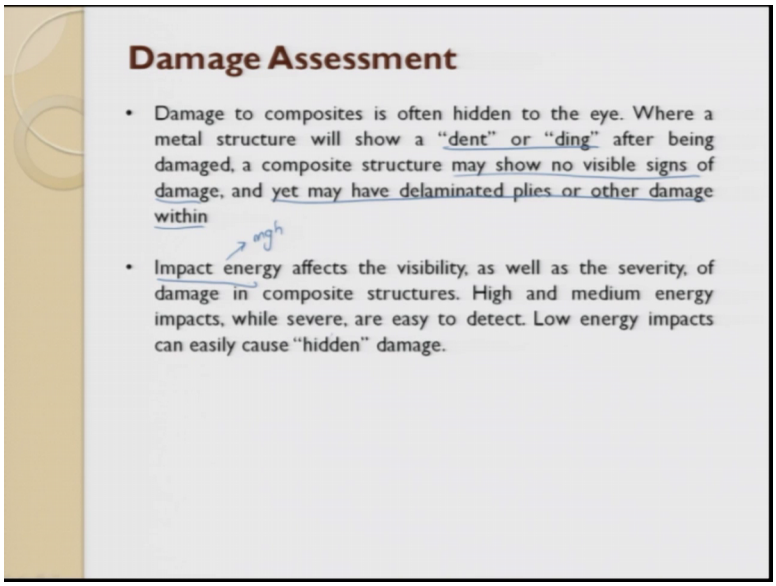

Any composite which undergoes a damage these are the repair procedures first inspect and find out where the damages come out with a strategy for repairing it, then try to repair the damage then after repairing please check for the quality assurance and then you go for finishing such that it can be put into good use.

So, what are the different types of assessments? So, the damage of a composite is often hidden. So, it cannot be done by naked eyes. So, what we do if we always go for a non destructive testing method to do it when a metal structure it can show up the dent and dent after being damaged in a composite structure may show no visible sign of damage and yet may have de laminated plies within it. So, what I am trying to say is if you look at the structure. So, here top and bottom it will be perfect. So, you will not see any defects, but in between in the core you will see lot of defect which are getting grown. So, that is what we are trying to explain hear.

The impact energy which I told you there are three different categories which it can fall. So, the impact energy affects the visibility as well as the severity the impact energy. So, how do you calculate the impact energy impact energy is its nothing, but the potential energy m g h right and then frequency also you will try to add? So, as well as effects the visibility as well as the severity of the damage in the composite structure high medium energy impacts while severe are easy to detect low energy impact can easily cause

hidden damages which the damage gets distributed. So, this is a typical higher energy impact.

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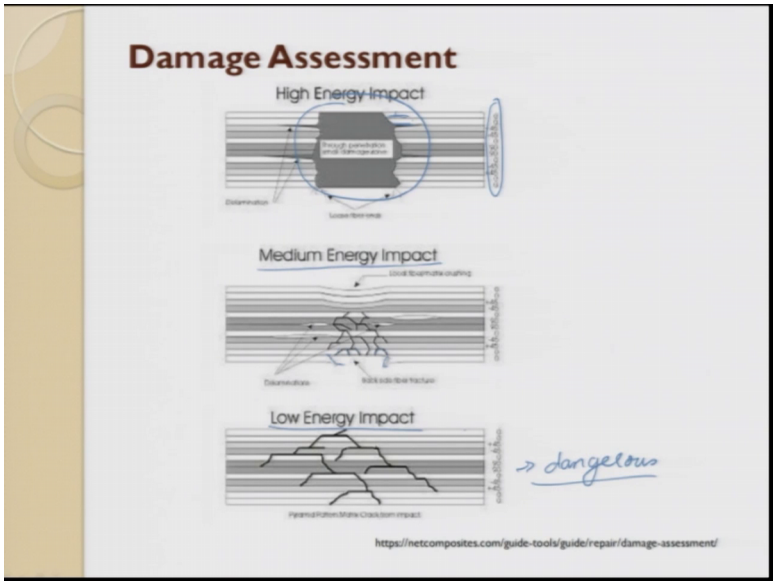

So, high energy impact you can see these are the laminates. So, when the impact falls the crack grows between the laminate. So, and then it tries de bond and then if the load is very heavy it tries to break open the break the composite or a drill through the composites and then goes to the other end. So, this is the damage which is created and these are nothing, but the de laminates which are getting formed between the layers. So, here are the different orientation of the composite which is used. So, this is a high energy impact high energy impact is for example, your bullet fired as against a composite. So, this is a high energy impact.

If you look at medium energy impact. So, here what happens there is a dent which is formed on the top the energy has to be dissipated. So, the energy is dissipated as the cracks which are getting formed in between the layers. So, you can see that the base you will have a small breaking out coming and then you will have in between cracks between the layers. So, it can be intra or it can be inter laminate cracks. So, these are the de laminations which are getting created at a very low energy impact there is no damage seen on the top there is no damage seen on the bottom its only the crack which grows all inside and it is very hard to find out, but it is a low impact; energy impact these are dangerous.

Many a times, these are the cracks which are not visible and it keeps growing over a period of time. So, in composites all you need is if you have initiated a crack this cracks keeps growing very fast between the layers and within a layer. So, high impact you can see very clearly and then it is there is damage medium again there is a small damage seen at the exit side in low there is no damage seen. So, this is the dangerous impact dangerous for the composite is concerned. So, this example is a bullet proof jacket as a bullet proof bullet firing and this is an example of a weights of maybe 2 kilos falling on top of a surface; this is a small spanner falling on a top of a composite surface with no damage, but creates a with no visual damage, but has a damaged within this material.

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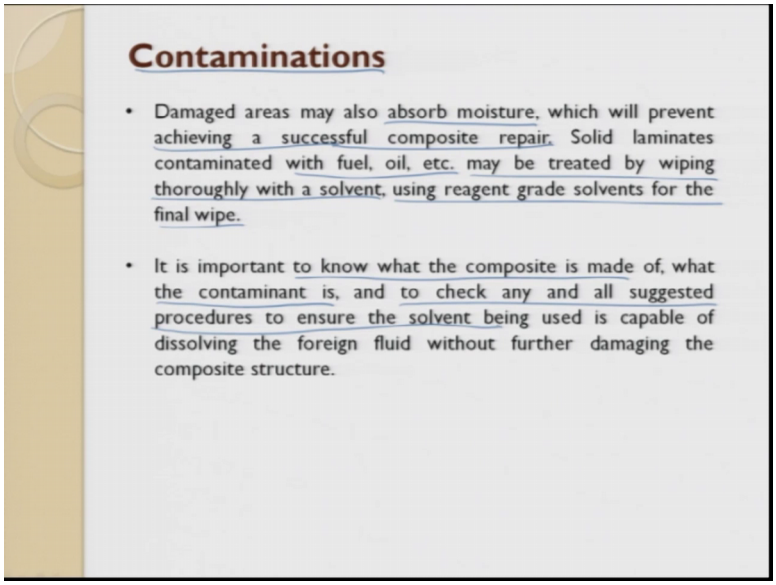

So, what are the different contaminates; the contaminates damage area may always absorb moisture because there are cracks and these cracks are and polymer is hygroscopic in nature. So, it absorbs the water molecules; so, which will prevent achieving a successful composite repair. So, what you do is first you have to remove all those contaminations the solid laminate contaminates with fuel, oil, etcetera, may be treated by wiping through with a solvent using a reagent grade solvent for a final wiping.

So, that what do you do is we somehow make sure this absorbed moistures are released out. So, this is very very important it is important to know what the composite is made of suppose whether it is made of thermoplastic thermosetting or thermoplastic what is it what is the effect of hygroscopicity; what is the effect of a solvent reacting to it all these

knowledge is required. So, it is important to know what the solid is made of what is the contaminate which is present there and we have to check for a procedure to and then choose a solvent such that the contaminants are removed from the damaged area.

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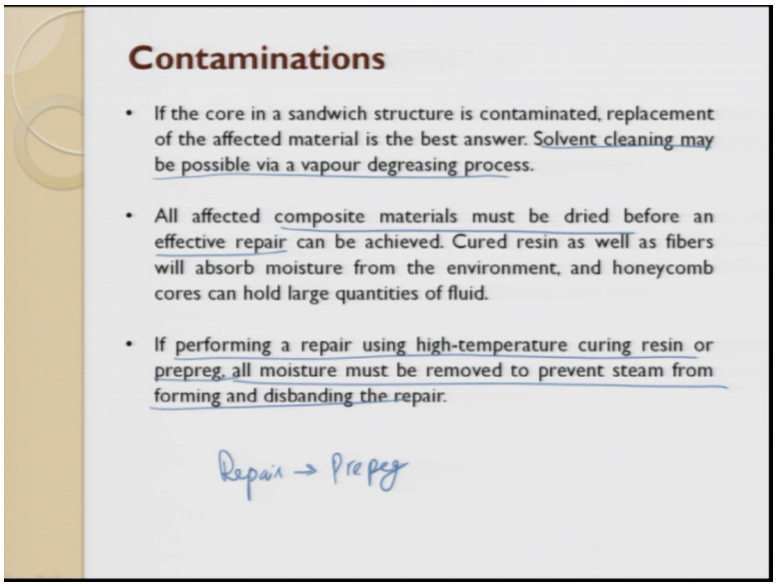

It is easy for a laminate suppose if it is there for a sandwich composite. So, in a sandwich composite if the core in a sandwich composite is contaminated replacement of the affected material is the best answer a core; suppose if the core; if it is not possible, then we have to look for alternatives. So, what we do is we do solvent cleaning and maybe possible, we will try to vaporize or we what we do is we try to degrease that part and then remove that part.

All the affected composite materials must be dried before repairing. So, that all the solvent is removed if you keep repairing in the presence of this solvents then that is going to be a disaster over a period of time then performing a repair using a high temperature curing resin or a prepreg all the moisture must be removed to prevent steam from the farming and disbanding the repair. So, if you want to do it; now it has been very clearly said for repairing you need to you always it is better to choose a prepreg and when you use a prepreg; it is good to remove the moisture and then start using it. So, the types of repair cosmetic repair suppose if it is only a dent on the surface.

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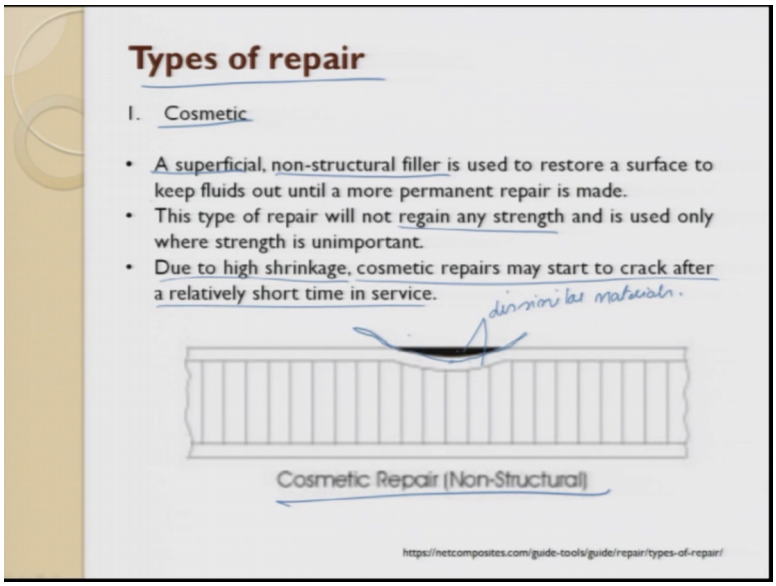

So, then what we do as we try to use a filler and then fill the place where the damage happened. So, a superficial or a non structural filler is used to restore a surface to keep fluid out of penetrating or getting fluid getting retained in the small dent; this type of repair will not regain any strength. So, it has no strength, it is only superficial. So, this can be thought due to very high shrinkage the composite repair my start to crack after a relative short period of time; that means, to say there is a difference in expansion or contraction with respect to the service conditions. So, there might be a crack which grows in this direction after a short period of time because of the dissimilar materials. So, this is cosmetic and there is a small dent on the surface.

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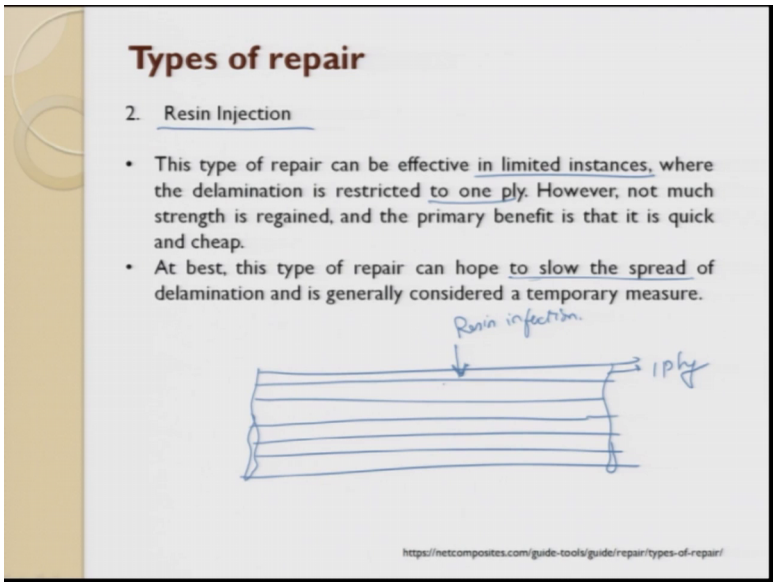

The next one is resin infusion. So, this type of repair can affect only in a limited instant where the de lamination is restricted only to one ply then we always go for one ply is just on the surface. So, this is this is a composite. So, you have plies. So, this injection can happen only in this direction. So, this is a layer. So, these are the laminates and this is a ply one ply. So, here the resin infusion injection or infusion injection; however, not much strength is regained in this it is again primarily filling up a gap which is there and it is very quick and it is very cheap and best this type of repair can hope to slow the spreading of this crack. So, this can be used for low impact where there is intra and inter laminate cracks this resin can inject and then start doing it.

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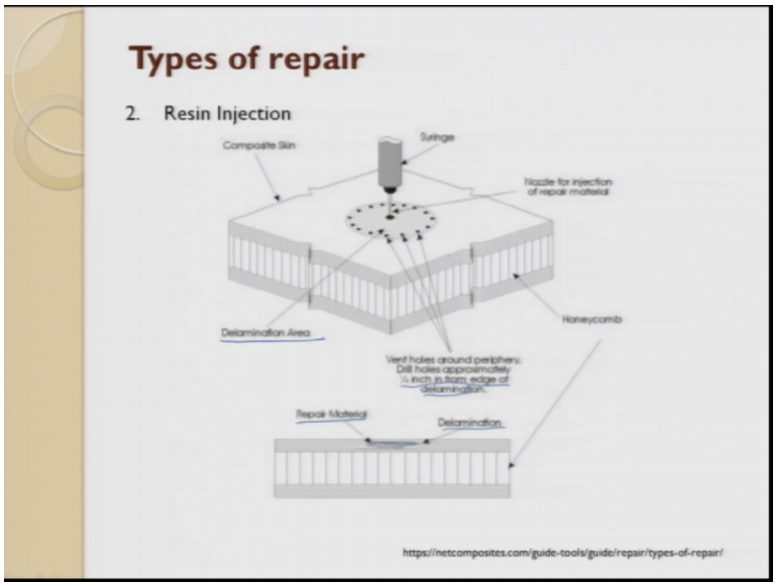

So, this is how it is a syringe is made through this syringe what we do if we try to push in the resin. So, that the this is a delaminated area and the vent holes around periphery drilled hole approximately one fourth of an inch from the edge of the de lamination we try to make small, small, small, small holes and then through that we try to infuse resin through this and then we try to see the damage. So, this is the repair material; this is a de lamination. So, this is a repair material. So, this is for a honeycomb structure and it can also. So, be used for one ply damage; that means, to say just below the surface.

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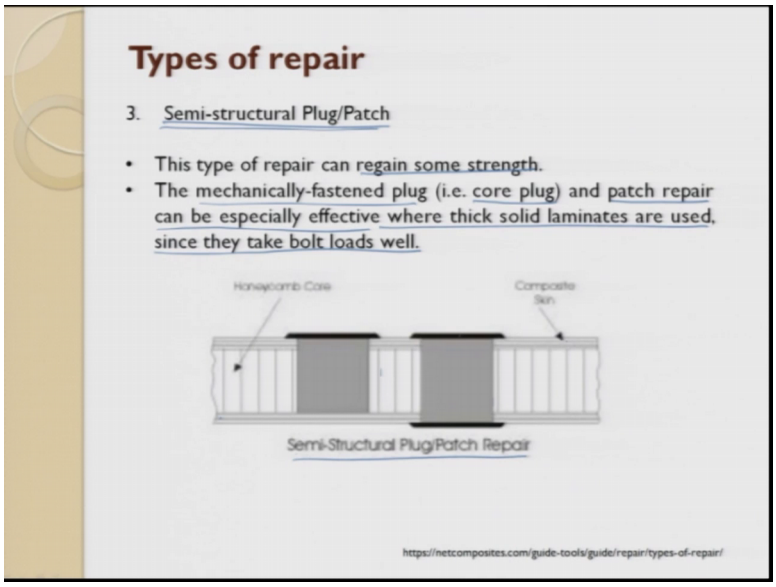

The next one is semi structural plug or patch. So, this type of repair can regain some amount of strength mechanical fastening plugs a core plug or a patch repair can be easily can especially effect where the thick solid laminates are used since they take bolt load as well. So, here what we are trying to say is here is the skin and here this is a honeycomb structure. So, here is a semi structural plug what we do is we put a plug in one direction or we put a plug in the one direction and then we close it in both sides.

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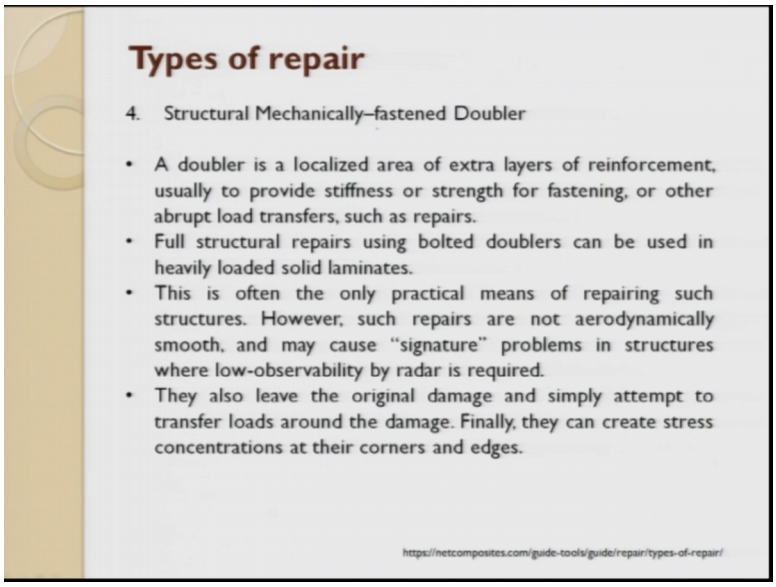

So, this one is called a semi structural plug or a patch which is done here it tries to take load then structural structurally mechanical fastened doublers. So, these are the doublers. So, here what do we do is we try to have bolt patch repair.

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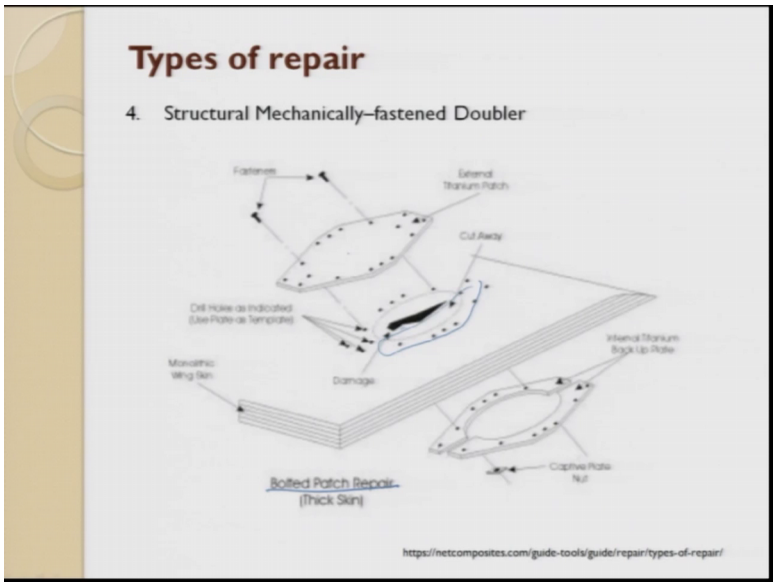

So, here what we do is we make small holes and then we tried to put a patch or a steel plate or something. So, this will have several holes. So, this patch is just put taking away the damaged area this is a cut away. So, then this is given on the top there is a plate on the top, then we fasten these 2. So, that we try to have a very good strength. So, this is called as bolted patch repair

So, here a doubler is a localised area of extra layer of reinforcement usually to provide stiffness or strength for fastening. So; or any other abrupt load taking such a repair; so, here this is what is which I discussed here. So, here this is often the only practical means of repairing such structures; however, such repair are not aerodynamically smooth and may cause signature problem in structures where low observability by radar is required.

So, when we try to do any of those damage repair, we try to introduce foreign materials which might affect the aerodynamic as well as the other the other radar application for signature whatever we got. Now the signature gets disturbed maybe this will try to change the radar response whatever you have.

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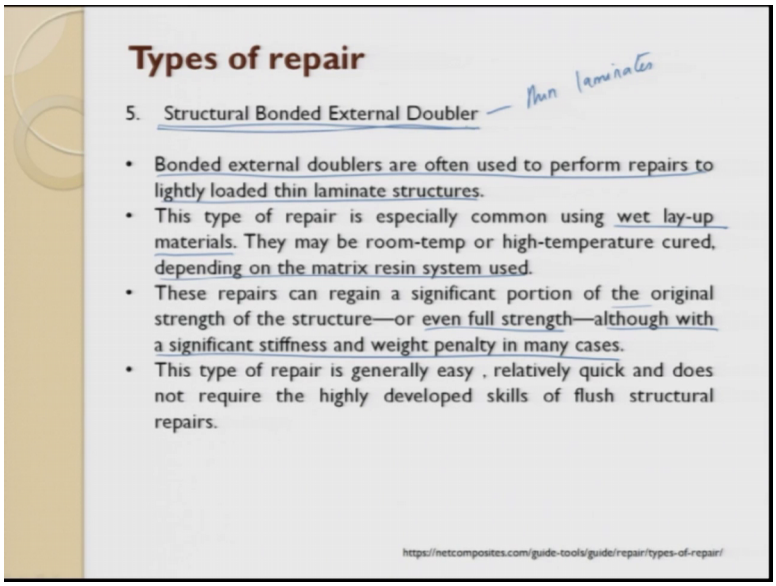

So, the last one is going to be structural bonded external doubler. So, here what we do is we try to bond external doubler are used to perform repair on the light loads on thin laminates we use. So, this is for thin laminates. So, it is especially common in wet layup material there maybe room temperature or high temperature cured depending upon the matrix of this resin. So, this repair can regain a significant portion of the original strength of the structure or even full although with the significant stiffness and the weight penalty in some cases. So, this technique is very commonly used for thin laminate damage techniques. So, structural bonded external doublers are used.

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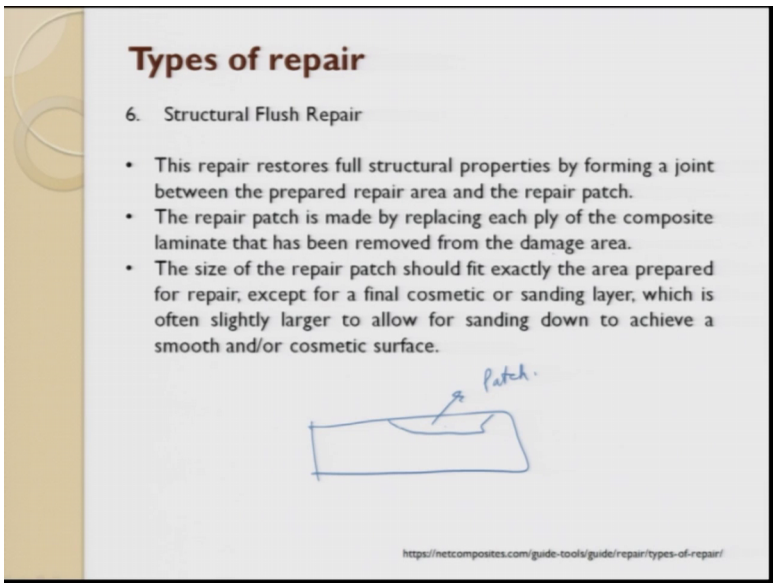

Then structural flush repair so, this repair restores full structural properties by forming a joint between the prepared repair area and the repair patch. So, a damaged area is there. So, this is a damaged area. So, you prepare a patch here.

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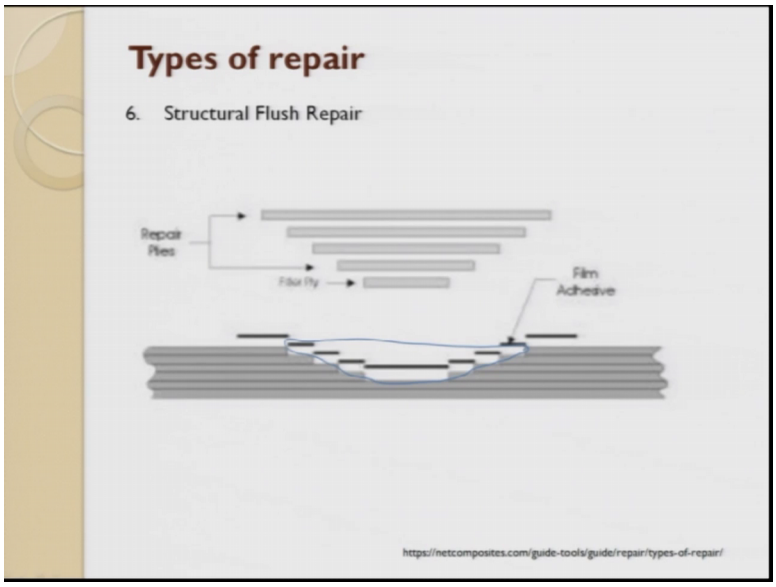

So, there is an attachment between the patch and the original material the repair patch is made by replacing each ply in a composite in a composite a laminate that has been removed from the damaged area. So, this is; what is a structural flush repair.

So, the structural ply what happens is. So, this is; what is a structure. So, we try to gouge out all the material from here and then what we do is we try to replace it with a cut laminate exactly 2 that gouged area. So, the plies will be cut accordingly even the orientation can be laid accordingly and then you try to get it. So, these are the fibres these are the original structure and these are the adhesives which are put such that this fellow and this can stick to each other to form a structural flush repair.

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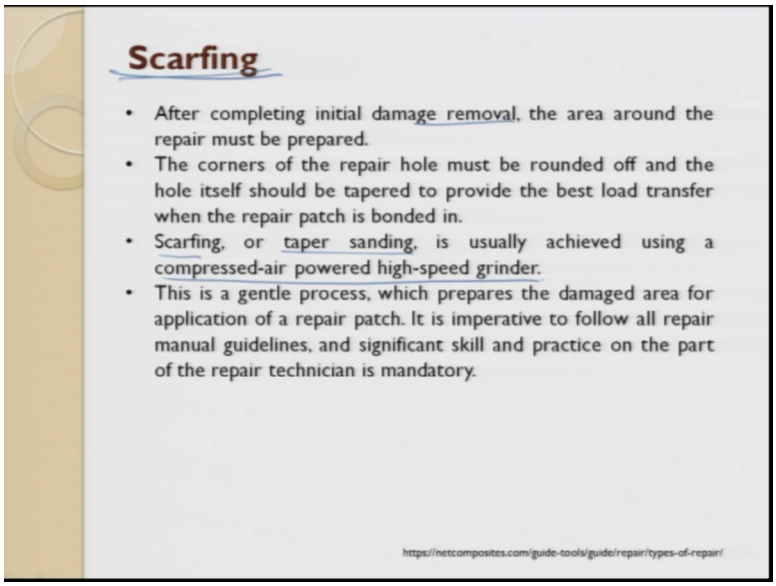

So, in this the strength is regained to a large extent. So, scarfing scaring after completing the initial damage removal the area around the repair must be ready. So, the corner of the repair hole must be rounded of and the hole itself should be tapered to provide the best load transfer when the repair patches is bonded to it.

So, basically what is what scarfing means is scarfing means that before the damage is completely removed the preparing the area for such way such that you try to get the best out of it the scarfing on the taper sanding is usually achieved by compressed air powder with high speed grinder.

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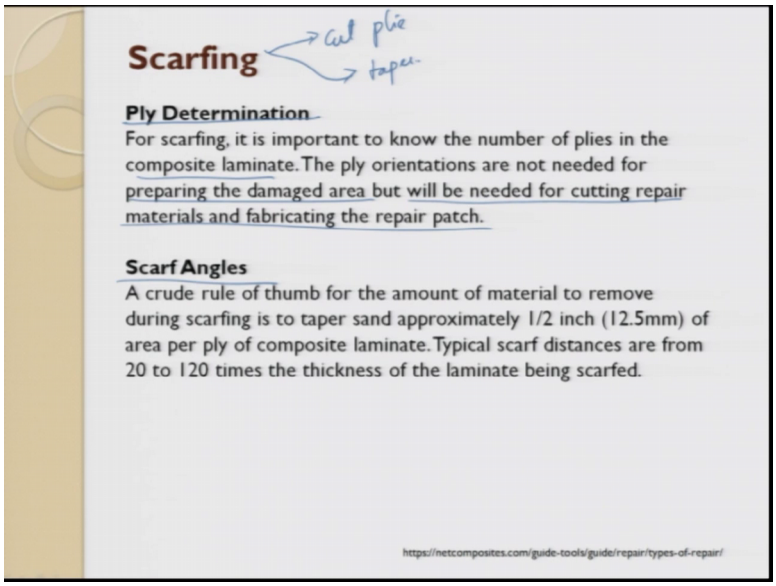

So, we prepare the area in trimming it such that we can have a proper patching. So, here it can be plyed termination on the scarf angle determination is 2 important parameters such that you get a proper scarfing. So, it is important to know the number of plies in the composite laminate the ply orientation are not needed for preparing a damage the damage area, but will be needed for cutting repair material and fabricate the repair patches. So, here as I told you first you have to cut the ply is important and then you have to make a taper. So, this 2 is done by the scarfing.

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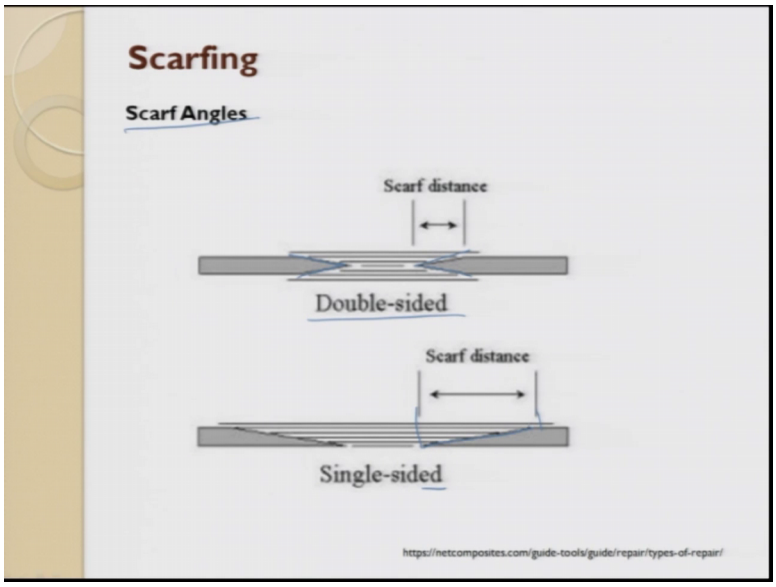

So, here is it. So, here you are damaged. So, here we prepare the double sided and then we put we find out the scarfing distance and then we try to put the layer. So, this is the scarfing angles. So, it can be single sided it can be double sided whichever you want you try to take and then you try to prepare. So, if you see that the scarfing and the distance is nothing, but from here to here we prepared such that you can have a proper repair patch.

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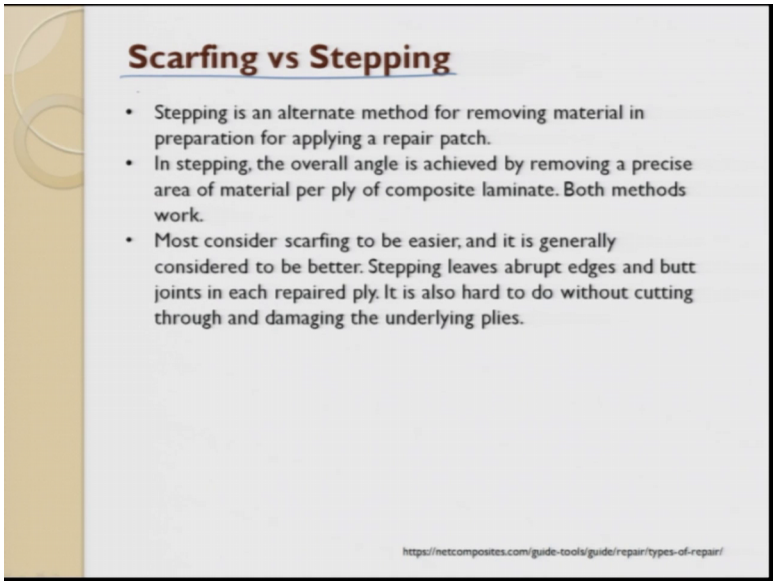

So, scarfing versus stepping; so, stepping is an alternative method. So, here in stepping; what do you do if we make it in to steps and in scarfing, we make it as a tapered angle. So, that is the difference. So, if you see the stepping is an alternative method of removing material in preparing for applying repair patch in stepping the overall angle is achieved by removing a precise area of the material ply of the composite laminate both methods scarfing and stepping works very good.

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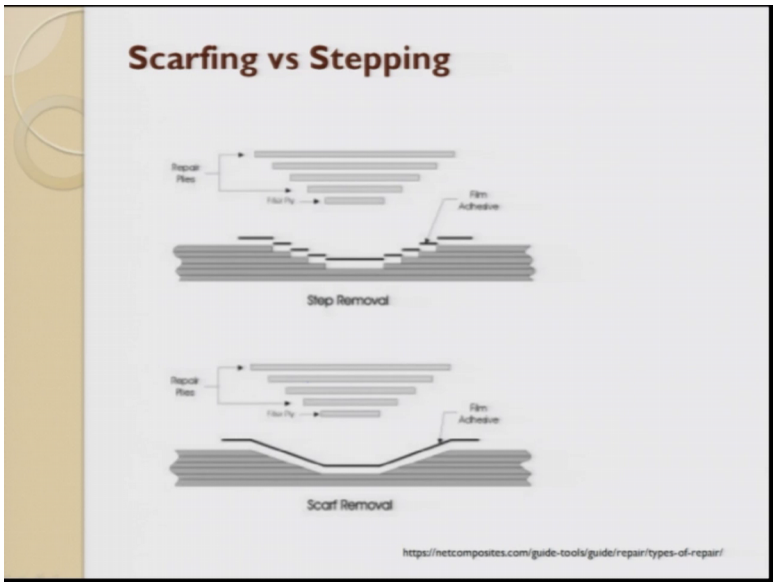

So, here is what is stepping. So, here this is; what is called as scarfing. So, you have a smooth transit here it is not a smooth transit.

So, with this we have studied the different ways of doing repair of composites. So, in repair of composite these are the steps which are involved which I would like to repeat. So, inspecting the assess damaged, then remove the damage material then treat the contaminates if at all there is any, then we try to prepare the repair area then complete the composite assess the quality whatever you have done and finally, we try to restore the finish such that you get the best out of it.

Thank you very much.