Processing of non metals

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Module - 07
Secondary Processing of Composite Materials
Lecture - 03
Joining Of Polymer Matrix Composites

A very warm welcome to all of you in this lecture on joining of polymer matrix composites. As you are well aware that this is the module number seven of our course one processing of non metals; we have seen the processing techniques for a large variety of non metals and now our focus is towards the secondary processing of non metals; whereas our focus primarily is on the composite materials and within composites our within the composites family our focus is primarily on the polymer matrix composites. In module number seven we have seen there what is the need of secondary processing and why secondary processing is required just to revise and to make a brief background of what we are going to discuss today. Secondary processing of materials is required in order to a certain there structural integrity into big products or huge structural products.

So, if we have to suppose make a building, in the building we cannot make the whole building in a single with the single process; we will make so many different components separately using such some of the techniques. And finally, all these parts would be assembled together they can be assembled by permanent joining process they can be assembled by temporary joining process. So, large number of parts would be joined together to make the complete structure.

Another example, suppose we want to make a automobile in an automobile different parts are made up of different materials some parts are made up of plastics, another parts are made up of metals, another parts may be made up of some of the alloys of the metals. And then we have all these different parts we have to combine these parts together to get the whole automobile. So, for joining or for assembling the total automobile we require a large variety of operations, and these operations fall under the category of joining operations or in another terms, we can call them as the assembly operations.

So, assembly operations and drilling or drilling and machining all these fall under the secondary operations. So, in order to ascertain the assembly operations sometime we

have to perform the machining operations specifically in terms of drilling. Suppose I want to join these two parts together one of the important types can be applying an adhesive and then making a joint, but in certain cases applying the adhesive may not be suitable alternative, then I need to make a hole inside the two plates and then use the mechanical fastening mechanism to make a joint.

So, joints are basically required to ascertain the structural integrity of huge products such as buildings and automobiles or even marine ships and aero planes. So, these are some of the examples where assembly operations are required, and where different parts manufactured independently are assembled together to get the final product.

So, as the title of today lecture goes joining of polymer matrix composites. So, there are two important terms in this particular title that is joining, and polymer matrix composites. So, joining is a very well developed technology, in which here are so many different techniques used for joining such as welding, brazing, soldering and there are certain mechanical fastening techniques, which are used for joining the various structural members into a big structure. So, joining is a well developed technique polymer matrix composites we have already studied in one of our modules that what are polymeric matrix composites, what is the matrix what is a reinforcement, and why the matrix and the reinforcement are combined together to make a composite, and how this composites are better as compared to the conventionally engineering materials, what are the application areas of the polymer matrix composite. And also we have seen at least eight to ten different techniques of processing of polymer matrix composite.

So, the title has been explained in with this discussion that we are going to focus on the joining aspects of a different class of materials that is polymer matrix composite. That what are the important issues and challenges, where that we encounter when we go for joining of polymer matrix composite we have seen that polymer matrix composites can be made in a different shapes made in different sizes. So, whatever techniques we have identified whatever techniques we have studied in our previous lectures on polymer matrix composite.

We have seen that all the techniques give us a composite product, but this composite product now has to be assembled with certain other materials or with another composite in order to get a complete structure. So, therefore joining of polymer matrix composites

is very, very important. So, we are going to focus on the issues and challenges, which are there in context of joining of polymer matrix composites.

Also, we are going to discuss another technique that is microwave joining of polymer matrix composite in our next lecture; that is lecture number four in this particular module of secondary operations for non metals are specifically for composite materials.

So, today our focus would primarily be on understanding that what is adhesive joining what are the we can say important or silent features of adhesive joining, what are the silent features in mechanical fastening, and then towards the and we would focus on that what are specific requirements, when we are going to joining two composite adherents using a adhesive.

Similarly, we will see that what are the issues and challenges, when we are going to join two composite adherents or adherents mean the two composite members. So, composite members, means that these are the structural members made by a composite material which composite material that is the polymer matrix composite material. So, here our adherents would be polymer matrix composite material, they can be in the form of a laminate or they can be in any other shape. And these will be joint with another materials either using a adhesive or using a mechanical fastening.

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Now, what is the necessity for polymer matrix composite joints; joining of polymer matrix composite has led to a new dimension of concern among the researchers. Why because it is not that easy as compared to the conventional engineering materials, we have seen so much of furniture if you take an example of a furniture wood is been joined to wood and using some or the other kind adhesive or some or the other kinds of mechanical joint wood is combined together different parts of wood and different shapes of wood are combined together to get the furniture. So, the joining techniques are well developed if we are talking about conventional engineering materials such as wood.

But if you talk about these advanced materials such as polymer matrix composite joining aspects need to be addressed properly or certain issues have to be addressed before the two composite adherents be joined satisfactorily making a good quality joint, which can take the loads that is going to come during the application of this particular composite material. So, joining of polymer matrix composites has led to a new dimension of concern among the researchers means, there are efforts worldwide to design and developed tools and techniques for the effective and efficient joining of polymer matrix composites.

Next on your screen you can see to ensure the effective utilization of the developed materials for the welfare of the society. Material joining becomes an important and necessary domain, which again emphasize the important of joining. Suppose we have designed we have invented a very good or we can say a very applicable engineering material, which has got lot of applications, it can be used in a large variety of applications the new material has been developed

Its application depends upon how effectively it can be joined with other members, so that it can be converted into a structure or into a particular application. Independently yes, there can be some applications, but many applications would be requiring this particular material to be joined effectively to other materials. So, this particular slide is just emphasizing on the role of joining of advanced materials that if we are able to join the advanced material properly, then the applications spectrum of this materials can be increased manifold.

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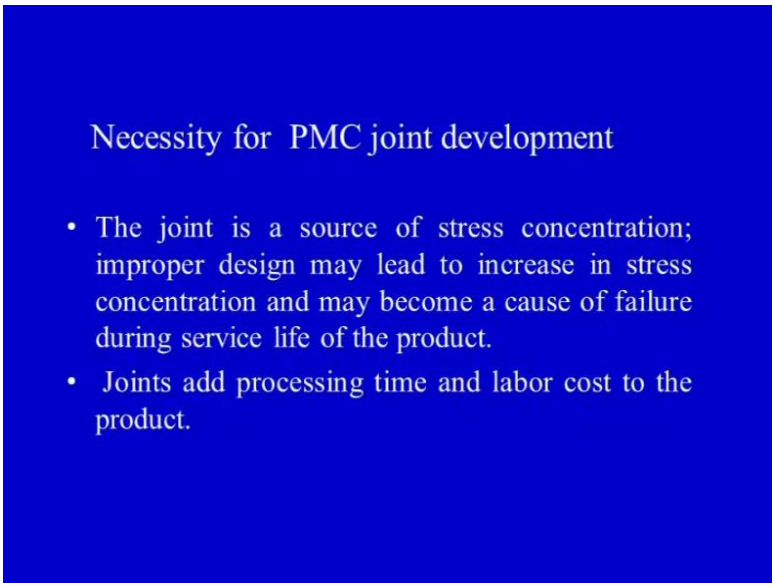

Now, necessity for polymer matrix composite joint development; the joint is a source of stress concentration everybody knows that improper design may lead to increase in stress concentration and may become a cause of failure during service life of the product. So, joint is an important, we can say part of the total structure, and most of the structures may fail at the joint. Otherwise also the structures may fail in the member itself if there is a huge structural member, the failure may take place in the bulk of the member also or in the material of the member also. But it has been found that joints attached one of the weakest links between the complete structures or in a completes structure. So, joint design and effective joining technique is a very, very important pre requisite to a certain the long life of the failure free life of the damage free life of a structure. So, joints add processing time and labor cost to the product.

So, joining and processing time joining adds processing time and labor cost to the products. So, certain times we would like to avoid the joining operations totally by making a nearness shaved products. Suppose I need a particular product for a particular application my focus would be to make it as it is without dividing it into four or five different components which latterly its to be needs to be assembled. So, the focus would be primarily to make a simple product, which requires no assembly operations. Why? Because joints add processing time and labor cost to the product. So, one approach can be that why not to totally avoid the joining process which is not feasible or possible in most of the engineering applications.

So, these two slides have given as an idea that joining of advanced materials is very, very important and we need to take proper care, when we are going to join the two structural members together. And today's focus is that these structural members are made up of composite materials that are polymer matrix composites.

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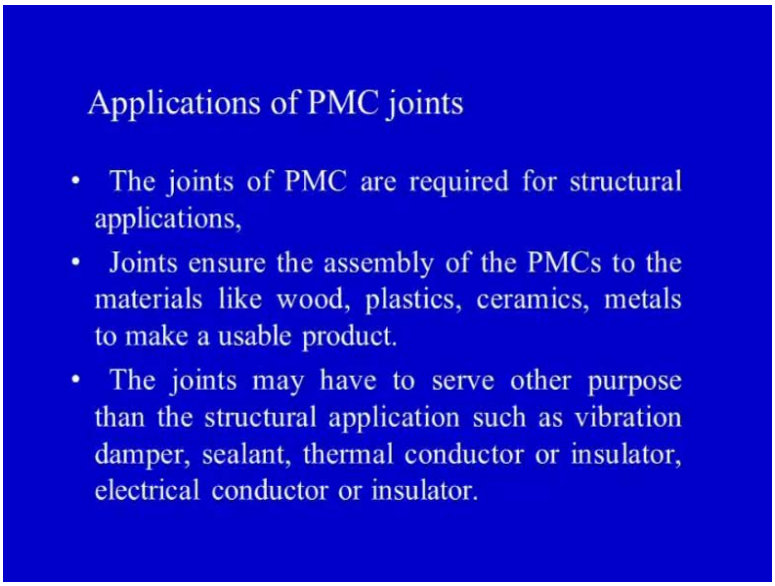

Now, what are the various applications of PMC joints we have seen that joints are important joining of PMC is very, very important; there are certain important aspects which are specifically related to the joining techniques for polymer matrix composite that we are going to see in the subsequent slides. But what are the applications where these joints are used the joints of PMC are required for structural applications which I have already told that if I have made two or three different composite parts or polymer matrix composite parts. And then this need to be assembled into the structural or into a particular structural application, then the assembly would be required. And therefore, the joints would be required.

Point number two on your screen joints ensure the assembly of the PMC to the materials like wood plastics ceramics metals to make a usable product, which I have already emphasize (( )) develop and new material I need to develop effective joining techniques for that material that how effectively it can be joined with other class of materials such as wood or plastics. So, that is another application of joints where the composite material is been joined with other materials, such as wood and plastic, why because when I have to

make complete product it may be have made up of five different materials out of which one is a polymer matrix composite another for made be a metal alloy a plastic and wood. So, I should have effective joining techniques so that this composite can be joined with other engineering materials; that is another application area where the joints are very, very important.

Next point the joints may have to serve other purposes sometimes the joints are made in such a way that they serve a lot of purpose such as in structural applications such as vibration damper. They can be used as vibration damper, they can observe the vibrations, they can be used as sealant thermal conductor of or insulator electrical conductor or insulator sometime the joints are designed in such a way that they act as or they serves the following purposes, which are there on the screen that they can act as vibration damper they can act as electrical or thermal insulator or conductor. So, joints are very, very important therefore, we need to understand the importance of joining.

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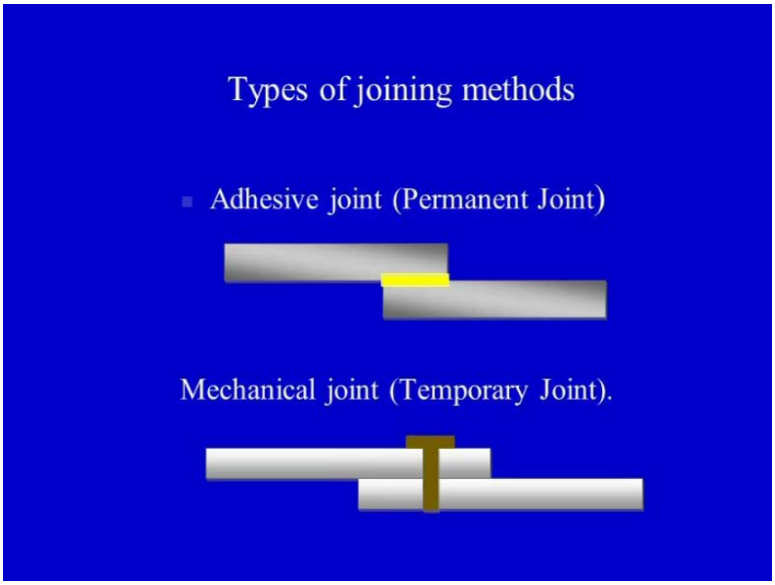

On your screen, you can see the two mostly used joining techniques or types of joining methods. So, first one is the adhesive joint which is a permanent joint means, the two composite adherents, when they have joined been joined together they cannot be dis assembled without breaking the joint. So, adhesive joint is a permanent joint on your screen, you can see this is one adherent this is another adherent; and this yellow portion

is the adhesive which has been applied. This is a lap joint, the yellow adhesive has been used to join the two composite adherents together.

Then we can have another type of joining method that is mechanical joint in mechanical joint. On your screen you can see this is the mechanical fastener, which has been used to join two composite adherents. Now this grey raw material are adherents are made up of composite material, they can be made up of any other engineering material, because this is a very general joining technique, which can be used for all different types of materials. This is just to highlight that what are the different types of joining methods, because these joining methods are also used for the polymer matrix composites.

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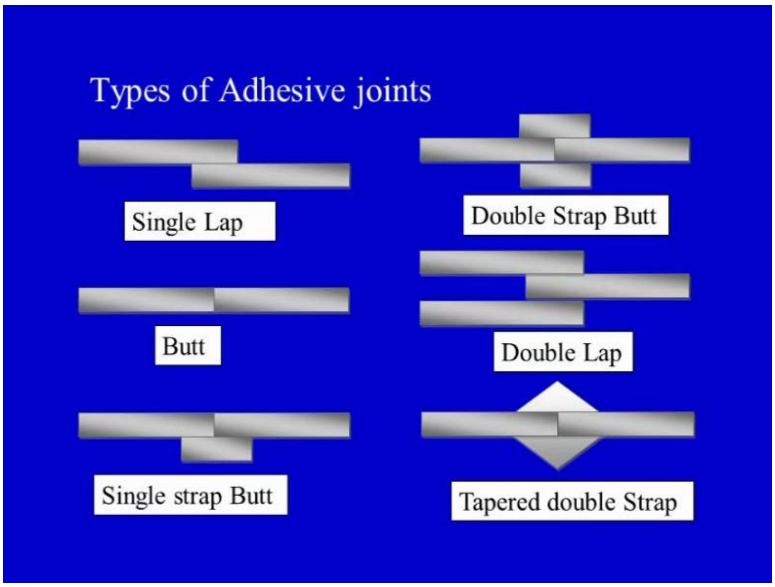

Now, these are types of adhesive joints, just for your reference that what how the composites can be joined using, which type of joint configuration or joint geometry. On your screen you can see, you can have a single lap joint, you can have a butt joint, you can have a single strap butt joint, a double strap butt joint, double lap joint or tapered double strap. So, there can be a huge or a large variety of joint configurations that can be used to join the composite adherents together, you need have the raw material which is a composite material. So, we have a composite laminate or composite plate and that composite plate can be joined to another composite plate or another wooden plate or another metallic plate using any of these types of joint configurations, by applying the adhesive. And then two can these two structural members can be joined together, but

there are few issues involved that we would be seen in the subsequent slide. So, these are certain or we can say important type of joint configurations or joint types, which are used for joining the composite adherents.

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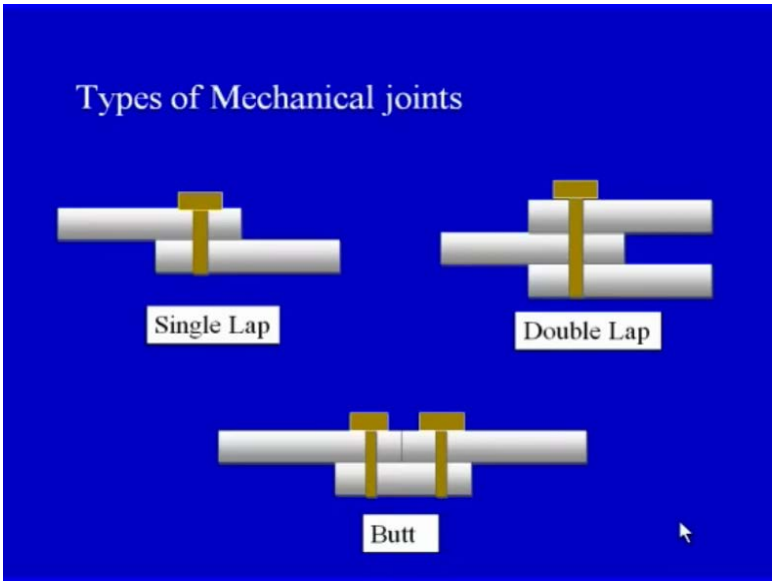

Then we have the types of mechanical joints, we can have again a single lap joint, which is shown here a double lap joint. On your screen, you can see and then a butt, butt joint is also there. So, we can make different types of joints in case mechanical joints also.

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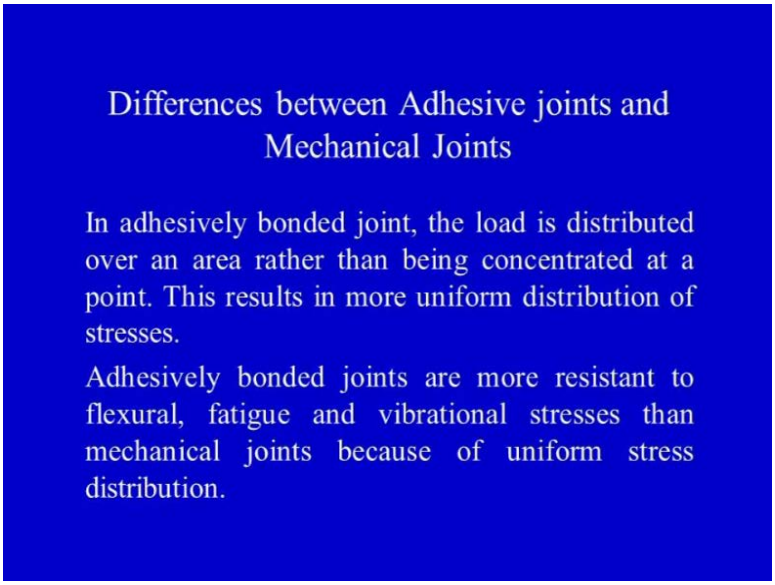

Now, what are the differences between the adhesive joints and mechanical joints, we have seen that what is adhesive joint, where we apply a adhesive between the two plates that we want to join together in case of mechanical fastening, we use the fastener to fasten the two make a composite plates together or the two structural members together. Now what are the differences because each one these has got certain specific application areas. So, on your screen, you can see in adhesively bonded joint the load is distributed over an area rather than being concentrated at a point for example, in mechanical fastening the load can be concentrated at the point, where the fastener is fastening the two composite plates together whereas, in adhesively bonded there is a bond area where the adhesive has been applied. So, the stress distribution is quite uniformed.

So, once again I am reading what is there on the screen in adhesively bonded joint the load is distributed over an area that is the bond area, where the adhesive has been applied and where the two plates have been joined together rather than being concentrated at a point as in the case of mechanical fastening this results in more uniform distribution of stresses. So, adhesive joints in such type of cases may provide to be a better alternative as compare to or may prove to be a better alternative as compare to mechanical fastening.

Adhesively bonded joints are more resistant to flexural fatigue and vibrational stresses than mechanical joints, because of uniform stress distribution. So, therefore, we can see that if we have a uniform stress distribution there joints are more resistant to flexural fatigue and vibrational stresses. So, adhesively bonded joints can be said to be more we can say effective, when more uniform stress distribution is desired.

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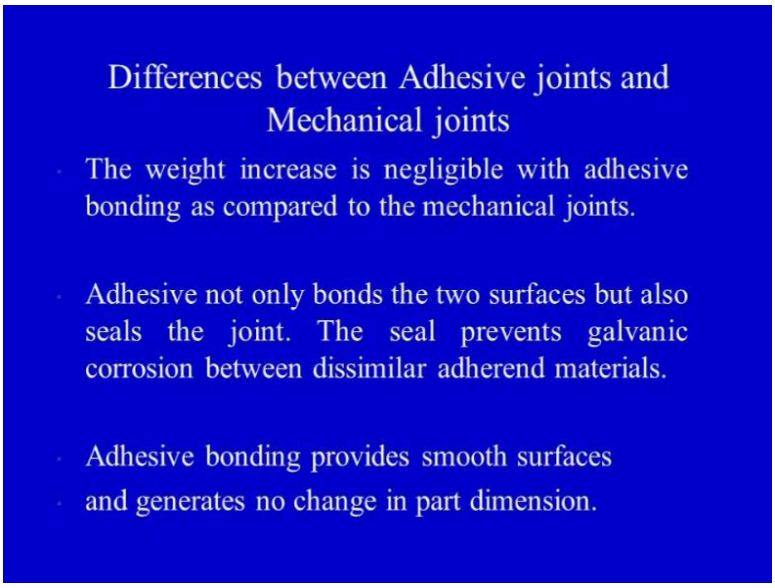

The weight increase is negligible with adhesive bonding as compared to the mechanical joint. Suppose we want to join a ten different places and we require ten different mechanical fasteners. So, these ten different mechanical fasteners would certainly add to the weight of the structure whereas, if we have to join two plates together we can apply the adhesive and join the two plates and the weight addition as we can see on your screen point number one the weight increase in case of adhesively bonded joints is lesser as compared to the mechanically fastened joints.

Point next adhesive not only bonds the two surfaces, but also seals the joint the seal prevent galvanic corrosion between the dissimilar adherent materials. So, we can have another advantage of adhesive joints that it not only forms the joints between the two plates or two composite adherents, but it also seals the joint. So, there is chances of leakage are also minimized more over it prevents galvanic corrosion also, when we are combining or when we are joining a composite plate with a non composite plate or a metallic plate or a any other plate in which the corrosion may take place. So, galvanic corrosion is minimized, when we are going to use a adhesively bonded joint as compare to a mechanically fastened joint.

Adhesive bonding provides smooth surfaces and generates no change in part dimension that is another advantages. Now suppose I have a uniform profile of the final component I do not want anything port loading out of the profile; in that case if I have to join that

profile with another profile, I would not like to have a mechanical head of the bolt coming out.

Therefore if I join it using a adhesive, I will be able to provide a smooth surface to the joint as well as to the structure. So, in if we do not want anything port loading out of the we can say structure and we want a complete smooth profile without anything on top of the surface, we would definitely go for a adhesively bonded joint.

Adhesive bonding is often less expensive and faster than mechanical joining that is that can be true in some of the cases, but in some other cases the mechanical fastening provide to be quick solution as compare to adhesive bonding. Specifically those cases where the adhesive that we are using may be requiring long curing time that we have already seen what do we mean by curing or in simple terminology get set ready means, after applying the adhesive the time required for the complete, we can say completion of the joining process, where the polymer or the chemical that we have used as the adhesive as completely form the joint. So, if the curing time is very, very large then the adhesive joining may also take lot of time. But in most of the cases, we can say adhesive joining is often less expensive and faster than mechanical joining.

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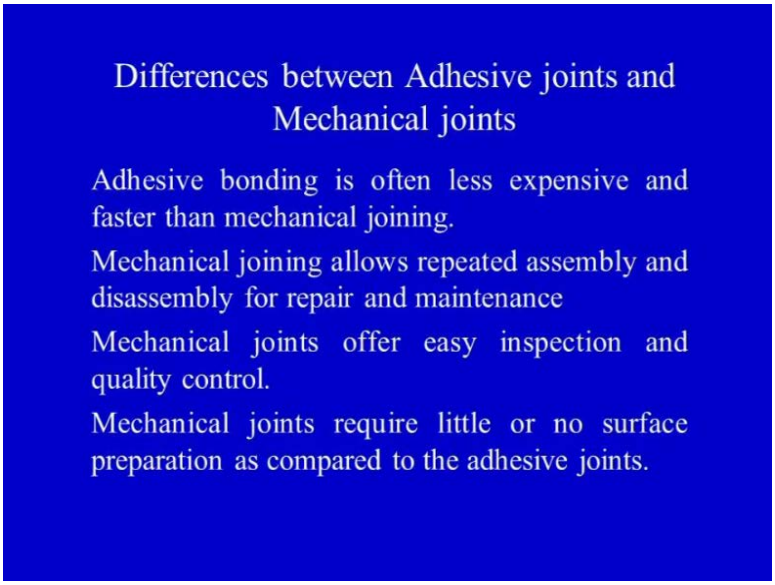

Mechanical joining allows repeated assembly and dis assembly for repair and maintain, now we come to the advantage of the mechanical joining till. Now, we have seen that adhesives are or adhesive joining is better as compared to the mechanical joining, but

here we see that when we have to have or regular maintenance of the structure which has been joined together using mechanical joining, we can dis assemble the structure and removing the mechanical fastener opening the structure doing the maintenance and then again closing. So, mechanical joining allows repeated assembly and dis assembly for repair and maintenance whereas, if we are join the same structure using a adhesive unit to break the joint and then only you can do the repair and maintenance. So, dis assembly is not possible with the adhesive joints whereas, dis assembly is possible with the mechanically fastened joints.

Mechanical joints offer easy inspection and quality control which is very, very obvious as compare to the previous point which we have already highlighted. Mechanical joints require little or no surface preparation as compared to the adhesive joints. So, therefore, adhesive joints require we can say surface preparation before the adhesive can be applied in order to get good bond strength. if we do not do the surface preparation the bonds strengths that we would get would not be of very high quality.

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Now, what are the factors that influence the failure of adhesively bonded joints, now these particular factors are particularly relevant in case of polymer matrix composite. So, on your screen, you can see there are large number of factors even there can be more number of factors, then what are listed on this particular slide, which affect the failure of the adhesively bonded joints. Now, we have already seen that what are the advantages of

adhesive joints, we have seen what are the advantages of mechanically fastened joints. So, when we have those advantages, and we are using the adhesive for joining purposes they are bound to be certain important factors, which we should keep in mind in order to avoid the pre mature failure of the adhesively bonded structures.

So, what are the important points silent features that should be kept in mind, while we are designing a particular joint which has to be adhesively bonded first of first, and foremost is the type of adhesive there is a huge variety of adhesive which are available. So, we have to properly choose that which type of adhesive would be able to provide as a good quality joint. Next one is the mechanical properties of the adhesive now each adhesive will have certain properties and these properties will dictate the failure of this particular joint, when it will be subjected to different types of loading conditions. So, mechanical properties of the adhesive also needs to be studied apart from the mechanical properties, there as to be other properties like the physical, and the chemical properties as well as the important points, such as toxicity and the other chemical inertness and other aspects which needs to be studied when we are going to use and these particular things would help us to make a joint which is good quality efficient effective, and usually leads the complete designed life of the structure.

So, we have seen type of adhesive mechanical properties of the adhesive, then comes the mechanical properties of the adherend are the structural members, which we are joining using the adhesive. So, these structural members are composites in our today's lecture and there is a big problem of de lamination in the composites. So, sometimes the adhesive may not fail even the bond between the adhesive and the adherend may not fail, but the adherend itself may fail. So, that is another problem. So, we have to see that what are the mechanical properties of the adherend? So, that it should be able to provide us good designed life of the joint. So, the adherends should also not fail. So, mechanical properties of the adherends also should be taken into account.

Then the bonding between the adhesive and the adherend also is very, very important in certain cases, it has been seen that the adhesive which has been used with a specific set of adherends does not bond with the adherend properly, and that leads to the failure of the bonding the adhesive does not fail the adherend does not fail, but the bonding between the adhesive, and the adherend fails and under a typical type of loading, this

particular structure is not able to take a load or this particular assembly of two adherend is not able to take the load.

Another important point that is the wettability of the adhesive the adhesive should be able to wet the two adherends properly and form a very good joint. So, wettability is also to be taken into account. Another important point is the surface properties of the joint surface. So, surface preparation is required otherwise the joint may fail or the bond strength at we get without the surface preparation of the adherends would not be as good as desired.

Then the type of loading is also very, very important. So, this we will try to understand with the help of a diagram, but pride to that we need to understand that what is the type of loading type of loading suppose we have a joint, we can have a tensile loading we can have a compressive loading e can have a bending load that is coming on that particular joint. So, our joint should be able to sustain, these type of loading. So, the point to high light here is that there are. So, many factors which needs to be taken care of when we are using the adhesive joining process to join the two composite adherends together.

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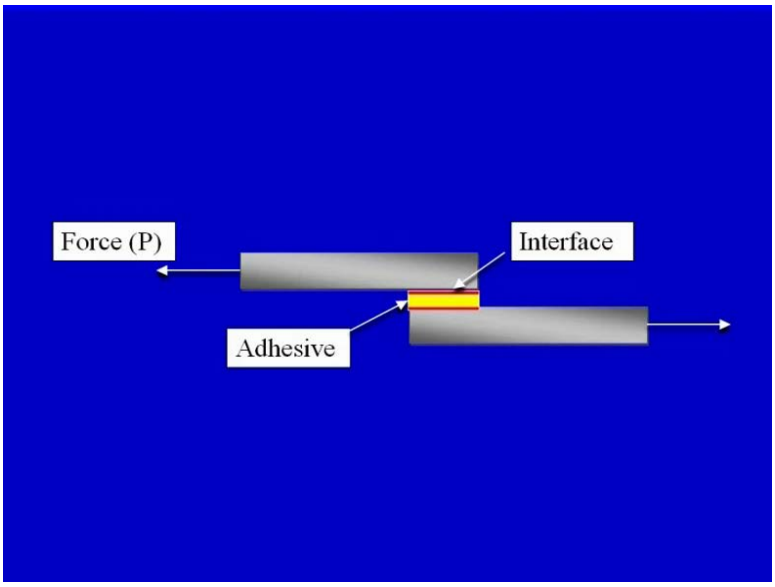

So, on your screen whatever we have discussed I will just once again revised, this is the adherend composite adherend, it can be made up of glass fiber reinforced plastic or carbon fiber reinforced plastic another adherend, which can be of the same material like

glass fiber reinforced plastic or carbon fiber reinforced plastic or can be any other material also type of material also.

So, we have two adherend this grey members are the adherends, and the yellow portion is the adhesive as is very clearly highlighted here with the help of a arrow yellow portion is the adhesive. And these red lines indicate the interface between the adhesive between the adhesive, and the adherend this is the adherend, this is another adherend, and this red lines indicate the interface very thin interface between the adherend and the yellow adhesive. So, this is the simple joint which has been made by the adhesive bonding. So, in this particular case the failure may take place, because of the type of loading here one type of loading is shown here can be different types of loading that may come on these joint, and that would dictate the failure of this particular joint that the failure mechanism or the failure initiation and propagation in this particular joint.

So, the type of loading the mechanical properties of the adherends; these are the two adherends the mechanical properties of the adhesive the bonding between the adherend and the adhesive these are some of the important points, and when we apply the adhesive we need to prepare the surface here and here. So, that proper bonding may develop between the adhesive and the adherends. So, if that bonding does not develop then there is every chance that this particular assembly of two adherends may fail under different types of loading conditions.

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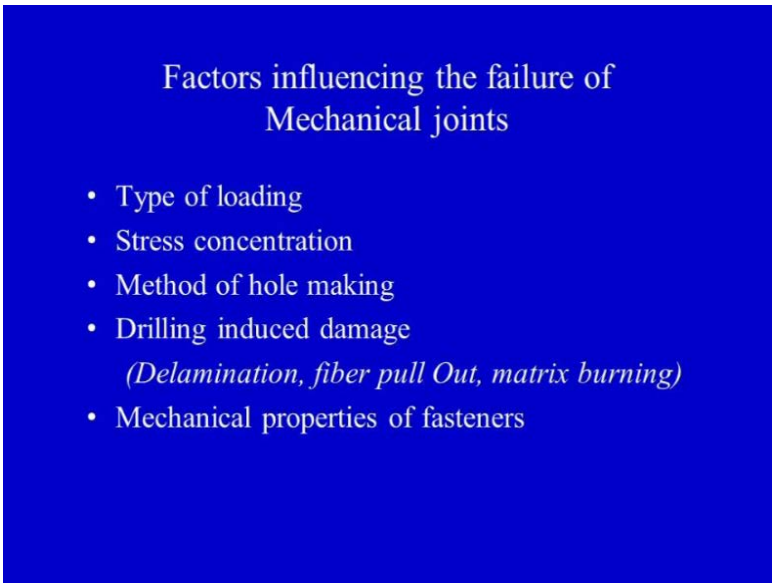

Now, factors influencing the failure of the mechanical joints now adhesive joints we have seen in case of mechanical joints different types of failure may take place. So, we have different types of loading similar to hat in case of adhesive bonding stress concentration because we are making a hole inside the two joints that with inside the two members which we are going to join. So, when a hole is there or any other structural dis continuity is there which may act as the stress concentration site.

So, there are different types of (( )) which act as stress concentration site, but in our case when we are trying to join two structural members together or in other terms or in simple term two plates together, we want to join using a mechanical fastener we need to make a hole in these two plates. And when a hole is made it will act as a site of stress concentration, that is another issue which may later on act as a failure site for the joint when the joint is loaded under different types of loading condition.

Next point the method of hole making in case composite adherends, if you remember lecture number one, and lecture number two we have seen that hole making is one of the most important and we can say one of the paramount important practices in case of composite materials it is a very, very important task why? Because it leads to a lot of damage around the drilled holes, so when we are using two composite plates or two composite laminates that we want to join together in order to make a assembly, if we require to make a hole the hole will definitely induce certain damage or it will generates certain damage around the drilled hole. So, which technique has been used for making the hole will also dictate the failure that would take place later on when this joint would be loaded under different loading conditions.

Next point drilling induced damage which is directly related to point number three, that is method of hole making, if the drilling induced damage, in terms of delamination or fiber pull out or matrix burning takes place this particular damage is certainly going to effect the behavior of this particular joint which has been made by mechanical fastening. So, in case of composite adherends, because this damage takes place the joints are not we can say very, very effective and efficient. So, the need of the or we can say one of the important points to be taken care of when we want to join two composite adherends together using the mechanical fastening technique is to minimize the drilling induced damage.

So, when these two parts have to be joined together when we have to make a hole in the two composite laminates due care should be taken to avoid the drilling induced damage, because if the damage takes place this particular damage is going to effect the behavior of this mechanically fastened joint of composite plates later stage. Then the mechanical properties of the fasteners are also equally important sometimes, we have seen the composite adherends even provide as the strength which is better than metals.

So, sometimes these fasteners are made up of metals only. So, the mechanical properties or the fasteners is also very, very important it may. So, happened that the composite adherends when they have been joined together with the mechanical fastener and the fastener is made up of for metal and it is loaded the adherends are able to take that load, but the failure of the fastener takes place why, because it did not had the requisite strength to take that load or did not have the requisite we can say power to take that kind of a loading. So, mechanical properties are the fasteners is also equally important in order to provide a very we can say durable life of the joint, which has been made by the mechanical fastening technique.

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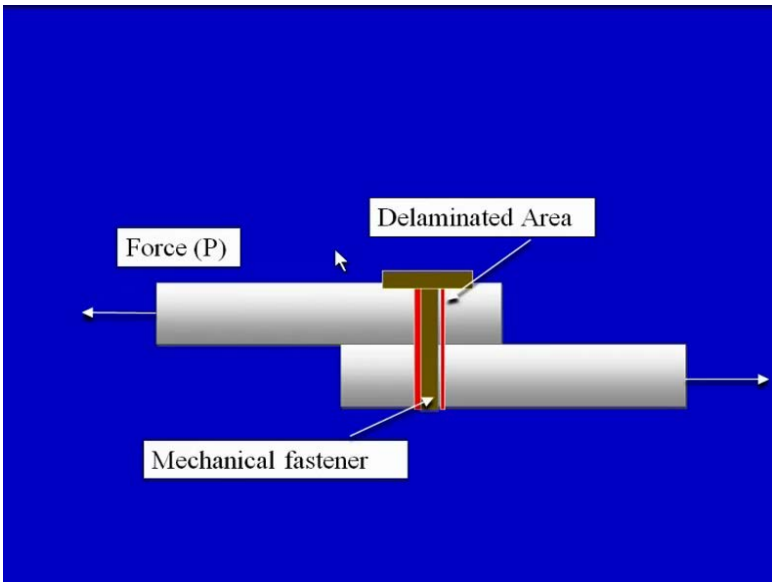

Now, on your screen what we have already discussed, these are two composite adherends adherend number one adherend number two, and the loading has been applies in between we have a mechanical fastener. And we can see this is exact type of delaminated area why this delamination in the adherends has taken place, because of the hole making

operations which we have already seen in lecture number one, and lecture number two that whenever, we try to make a hole inside the composite laminate there is bound to be certain damage that is all around the drilled hole.

So, this red portion shows the damage which has taken place around the hole this particular hole and this particular hole, which has been made in the composite adherends with the drilling operation. So, when this will be loaded the fastener may not fail, but the adherends may fail because of this induced damage which has already present before the actual fastening process. So, there are certain specific issues related to the adhesive joining and mechanical fastening of the composite adherents, now we will try to briefly high light that what are this important issues.

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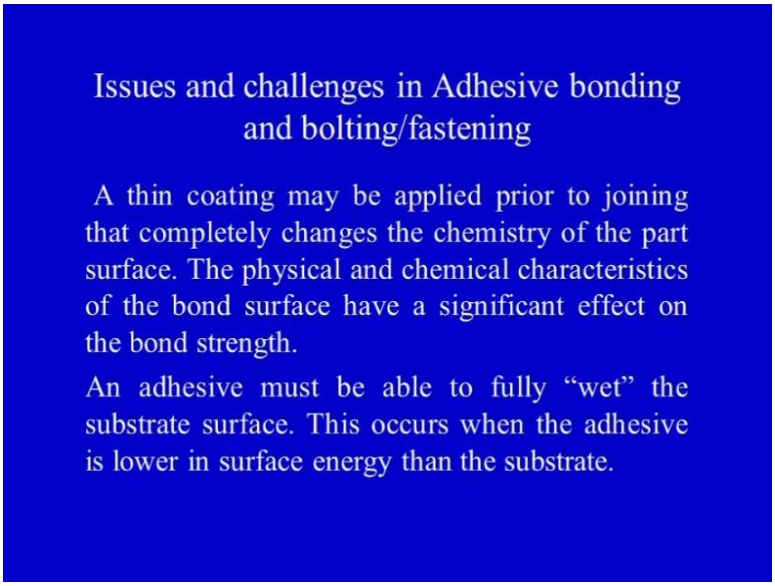

Now, these are issues and challenges in adhesive bonding and mechanical fastening or bolting a thin coating may be applied prior to joining that completely changes the chemistry of the part surface. So, we want to do the surface preparation of the composite adherends before the actual joining process in order to get a very good bonds strength the physical and chemical characteristics of the bond surface have a significant effect on the bond strength. So, the summary of this particular point is that if we want to get a good bonds strength, we need to do the surface preparation of the two surfaces on which we are going to apply the adhesive in order to form the adhesively bonded composite joint.

Point number two an adhesive must be able to fully wet the substrate surface this occurs when the adhesive is lower in surface energy then the substrate or the adherend. So, the summary of point number two is that the wettability of the adhesive should be good and it should be able to wet the total bond area in order to form a very good quality adhesive joint.

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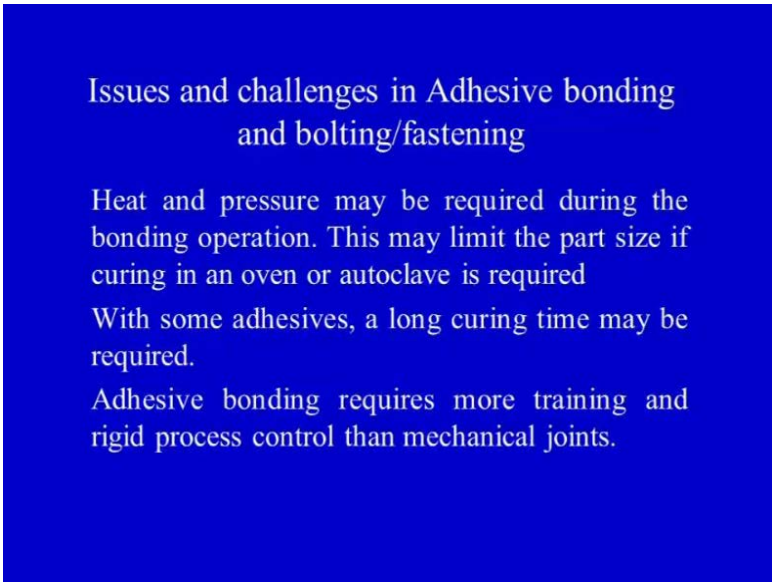

Heat and pressure may be required during the bonding operation this may limit the parts size if curing in an oven or autoclave is required. So, sometimes we may be requiring to put heat and pressure while we are doing the adhesive boding, and if this heat and pressure has to be applied in the autoclave, which we have already seen as one of the techniques in one of our previous lectures. So, if within a autoclave we have to make this joint by applying pressure and heat, then the total size of the part is limited by the size of the autoclave, because we cannot put a very big size component or a assembly in the autoclave. So, that is another important issue that is associated.

With some adhesives a long curing time may be required as I have already highlighted in today's lecture that adhesive bond have a certain advantage their quick, and cheaper as compare to the mechanical fastening, but if the curing time of the adhesive is long then the adhesive bonded joints may be taking a huge amount or may be a large amount of time before the final joint is ready. So, long curing time sometime is an issue with the adhesive bonding joints. Adhesive bonding requires more training and rigid process

control than mechanical joints. So, the technique and the, we can say requirements of adhesive bonding are we can say more skill full as compare to the mechanical fastening process.

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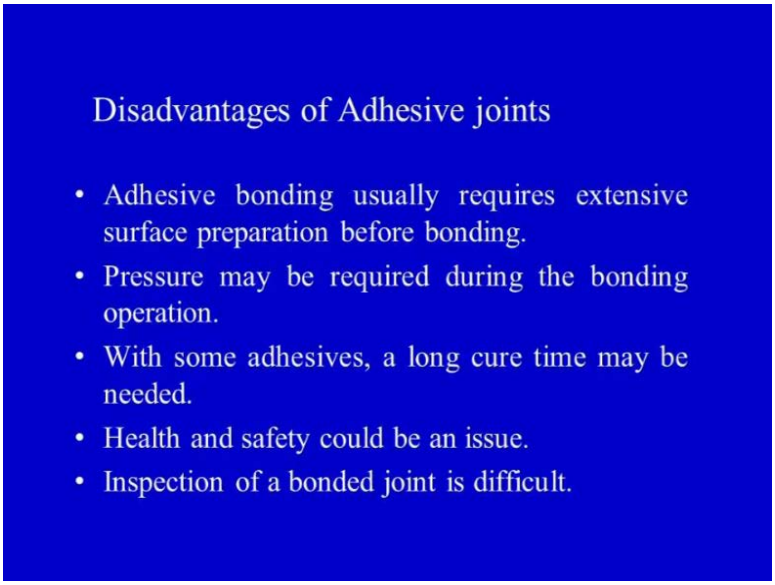

So, now we will see the summary of disadvantages of adhesive joints and disadvantages of the mechanically fastened joints, why because of our next lecture is on micro wave joining of polymer matrix composites in which we will see that what are the disadvantages of adhesively bonded joints, and mechanically fastened joint which are overcome by the micro wave processing techniques. So, this is just a summary of what we have already covered in today's lecture that is what are the adhesive joints, what are the mechanical joint, and what are the specific requirements in case of composite when we are talking about the mechanical fastening of polymer composites, and the adhesive joining of polymer composites. So, we will just now summarize the disadvantages of both the techniques.

First important disadvantages is adhesive bonding requires extensive surface preparation before bonding that area, where the adhesive as to be applied needs to be prepare before the actual adhesive bonding to take place next point pressure may be required during the bonding operation as we have seen that auto clave may be required in certain instances with some adhesives a long cure time may be needed and thus the total process of adhesive joining may take a long time health and safety could be an issue, why, because

the adhesives are chemical substances and sometimes they may react with the composite, because composite also has the polymer matrix which is also a chemical. So, when these two chemicals are coming in contact and we are supplying heat in some cases there may be certain reaction, and certain fuse may be generated which have to be avoided. So, before using a particular type of a adhesive with the particular type of a composite adherend due care should be taken in order to avoid this health and safety issues. Inspection of a bonded joint is difficult which we have already seen that the adhesive joining forms the permanent joint, which is not easily possible to disassemble. So, if we want to do a inspection within the joint it is sometimes not possible.

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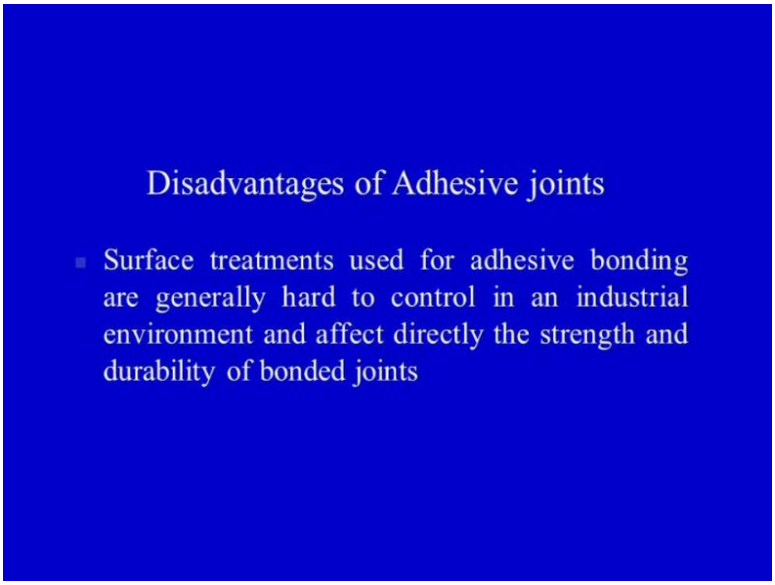

Another important point surface treatments used for adhesive bonding are generally hard to control in an industrial environment and affect directly the strength and durability of bonded joints. So, another important point to note is that the surface preparation is a tedious task, and if it is not done properly there is every chance that we may not get a very good bonded joint. So, surface treatment is difficult to control in many cases.

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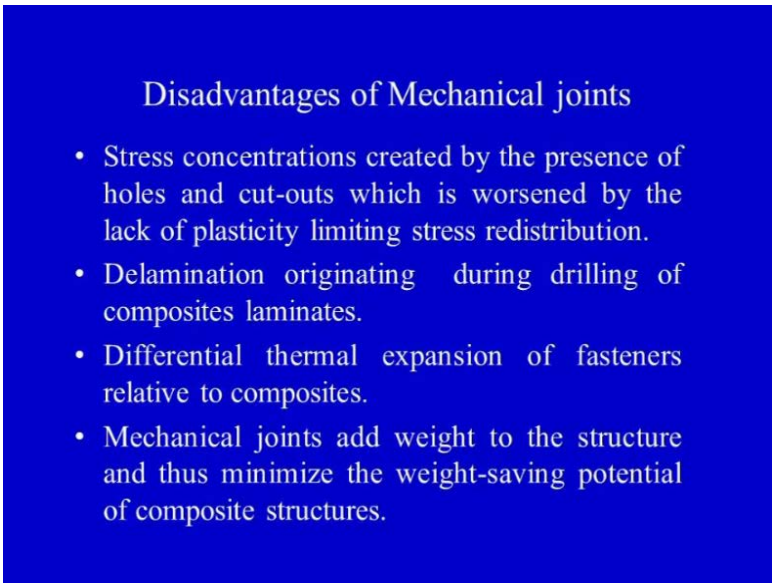

Now, what are the disadvantages of mechanical joints one of the most important disadvantages stress concentrations created by the presence of holes and cut outs, which is worsened by the lack of plasticity limiting stress redistribution. So, summary of this particular point is that stress concentration definitely takes place around the holes and the other types of cut outs which needs to be avoided, but which is un avoidable when we have to do the mechanical fastening why? Because when we want to use the mechanical fasteners we need to have holes in the composite adherends. So, this stress concentration is an issue.

Point number two delamination originating during drilling of composite laminates, which we have already seen specifically in case of laminated composites or specifically in case of polymer matrix composites delamination is a big issue, when we make a hole that plies or the layers or the laminate and (( )) delaminate. And when the reappears through or it goes through the laminates delamination takes place, and this delamination acts as a failure initiation site, when this particular component is subjected to different types of loading now suppose I have one component or one plate on top of it, I have another plate. So, these two plates have been have to be joined together with mechanical fastening, and I make a hole in this two plates I make a hole in this plate and I make a hole in this plate, and put this two plates together and use a mechanical fastener, if these two plates are made up of a composite adherend or laminated composite there is bound to be delamination which may take place.

And when I am using a mechanical fastener to bound, these two plates together or to assemble these two plates together, and then loading this assembly this particular delamination, which is taken place because of the drilling action on the laminates will certainly affect the performance of the assembly. So, that is another issue or delamination that take place in the composite adherends.

Next point differential thermal expansion of fasteners relative to the polymer composite. So, the two materials are different fasteners are usually made up of metals and the composite are usually made up of the fibers and the polymers. So, the thermal expansion is bound to be different. So, if the joint is been used under elevated temperature thermal expansion may be different and may act as a cause of failure.

Mechanical joints add weight to the structure, and thus minimize the weight saving potential of composite structure, as we have seen in our previous lectures that the use of composites is advocated in specific circumstances, where weight saving is one of the prime designed criteria. So, composites structure are used where we want to save a lot of weight, but when we are using mechanical fasteners the weight of the fasteners would add to the weight of the structure. So, therefore the basic criteria of weights saving which we can get with the composites structure sometime is compromised in case of the mechanical fasteners, because mechanical fasteners than reduced the weights saving potential of the composites structures.

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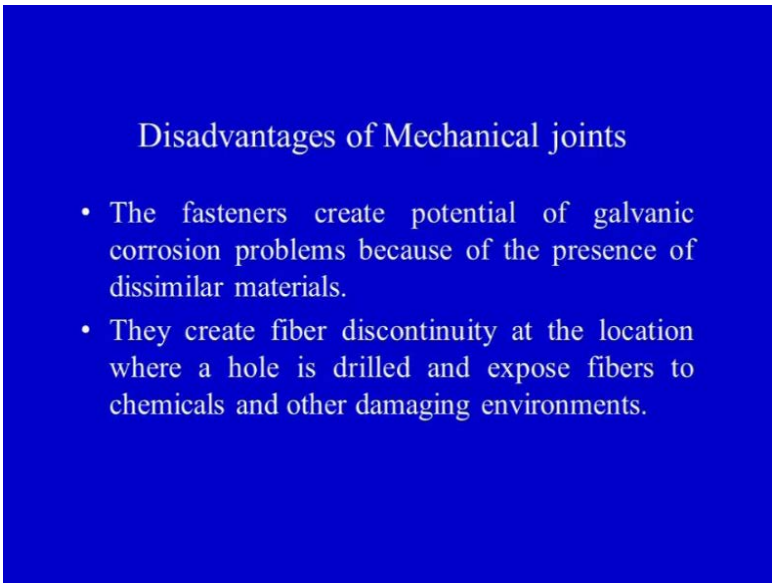

The fasteners create potential of galvanic corrosion, because of the presence of dissimilar materials, because fastener as I have already seen would be of a different materials as compared to adherends because adherend in our case are composite adherends. So, when composites are in contact with any other material the chances of the galvanic corrosion are aggravated. So, that is another disadvantages of the mechanical joints.

Finally they create fiber discontinuity at the location, where a hole is drilled and expose fibers to chemicals and other damaging environment again, this is related to the drilling induced damage of composite laminates or composite adherends, when the damage takes place at the hole valve there are micro wades or there are small cracks that are developed. And when this joints suppose is subjected to a damaging environment there are chances that the moisture may go into these cracks, and may cause a failures site.

And then there other chances some chemicals may peak into or seep into these micro channels which have been generated, because of the damage around the drilled holes and may certainly affect the in service performance of the mechanically fastened joint. So, there are certain issue related to the adhesive bonding of polymer matrix composites, and the mechanical fastening of the polymer matrix composite which have to be looked into in order to provide a good service life of the joints.

So, summarize what we have covered in today's lecture, we have seen what is mechanical fastening what is adhesive boding, we have seen what are the issues and challenges elated to mechanical fastening and adhesive bonding specifically in case of polymer matrix composite. We have try to understand with the help of diagrams, that how interfacial debonding may take place or what are the important factors, which may lead to failure of a adhesive joint in case of polymer matrix composites, we have also seen that what are the factors which may lead to a failure of a mechanically fastened joints specifically in case of polymer matrix composite.

And finally, we have seen that what are the disadvantages of the adhesively bonded joints, and the mechanically fastened joints, so that we can lay a foundation of discussing the micro wave joining of polymer matrix composite. So, in our next lecture in module seven we would focus on the micro wave joining of polymer matrix composites.

Thank you.