Processing of Polymers and Polymer Composites

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Lecture – 28
Secondary Processing of Polymer Composites

[FL] Friends welcome to session 28, in our course on processing of polymers and polymer based composites, as I have already explained and we finished our session 27, with a summary of the course, the course basically is divided into three phases and phase one is related to polymers and processing of polymers and phase 2 is related to processing of polymer composites and the third phase. Now, that we are going to start, today is processing of polymer composites with emphasis on secondary processing of polymer composites.

Now, phase 2 and three are interrelated, why; because in phase two, we have seen what are composite material, how they can be classified, what are the specific properties of these materials, what are the examples of composite materials, then we have identified one particular class of composite materials, that is polymer matrix composites, sometimes they are called as the fiber reinforced plastics also. So, these FRPs, we have seen that what are these, how these can be processed and in processing, if you remember we have seen. So, many processes starting with hand layup process, spray layup process, compression molding, resin transfer molding, compression molding, injection molding, then we have seen pre preging, then we have seen sheet molding compound. So, different processes are used for processing of polymer matrix composites.

Now, the question is why secondary manufacturing is required? When we can make our products? We have seen in the videos, the ship building, we have seen how flat plate composite laminates can be made flat plate type of composite laminates can be manufactured. So, we know how circular axis symmetric type of composite products can be manufactured. So, we know flat type of products, how they can be manufactured circular cross sectional product? How they can be manufactured, big size products like a ship? How they can be manufactured small size products like a toothbrush handles? How they can be manufactured? So, we have seen that how products can be made using polymers in our phase one and using polymer matrix composites in our phase two, then

why there is a need for the third phase, that is the secondary processing or secondary manufacturing of polymer matrix composites, that is the answer. We are going to look for, in our today's session, that why secondary manufacturing is required and what are the various techniques tools, that are use for secondary processing of polymer matrix composites.

If you remember, we have discussed earlier also that using the primary processing techniques, we can make, we can process, we can fabricate, we can manufacture different types of composite products, but when we have to convert that product into a tangible product into a structure, into a complete assembly. So, this composite part or product or component that we have processed using, anyone process for example, maybe filament winding. Suppose, we have made a very large size oil storage tank or water storage tank, using filament winding, how we will cut a window, where we have to place the assembly through which we will have our water or oil or milk or whatever storage media that we have developed this tank for.

So, I am trying to explain that we have made a very big size fiber reinforced plastic or a polymer matrix composite tank, storage tank it can be made. Now, suppose, we have to convert it into a usable product, we need to cut windows through which we will input our liquid media, for which the tank has been made, we will have to design a system. So, that whatever is stored inside can come out easily from the tank. So, for a complete structure to be developed, we need the secondary manufacturing. So, it may include joining operations. It may include machining operations, it may include heat treatment of the product, it may include finishing of the product, it may include and edge trimming or end trimming of the product.

So, secondary processing techniques are equally important to realize the potential of these polymer matrix composites, because we can very easily make a composite material, using the standardized and commercialized processes, which are already available. We have machines, we have a pultrusion machine, filament winding machine, compression molding machine, injection molding machine. So, commercial machines are available which can help us to produce the products or the composite parts, but when the different parts have to be combined together, there is a challenge and that challenge is how to ensure a good quality assembly between the different types of adherent. So, different types of members or different types of components or parts.

We may have made 2 parts, maybe one by pultrusion process, another one by filament winding, the 2 different parts have good quality made by high quality, cost effective manufacturing processes, for polymer composites, both processes are fully commercial pultrusion also and filament winding also, but now in order to convert this complete product into a tangible. We need to combine these 2 parts together and for combining the 2 parts, we require the secondary manufacturing or secondary processing of polymer matrix composites and we cannot do a way without understanding the basic intricacies, involved in the secondary manufacturing processes.

We may have become expert, the learners also are expert. Now, in the primary manufacturing processes, you can look at very different types of videos available on YouTube and other sites, free sites, try to understand the process. You may get lot of information related to whatever processes. We have covered, there will be very popular videos, it which, in which you can try to understand the processes, but there is very less literature, very less information available on the secondary manufacturing, that how to join the polymers together, how to join the polymer matrix composites together and for that still research efforts are on people are working and trying to develop new and new processing roots for joining of the polymer as well as polymer matrix composites.

So, today's session is just an introductory session, just highlighting that what are the various techniques, which have been established for joining the 2 composite parts together and we will see that may be wherever possible I will try to address that what are the challenges in that process and in our subsequent sessions. We will see, maybe each process, one time may be drilling of polymer matrix composites, we may spend, may be 2 sessions on drilling operations, only for polymer composites. Now some of you, may be wondering, how all of us sudden drilling as coming to picture, because when you have to join to composite parts together, drilling is one of the unavoidable machining operation, because you need to make a hole in the 2 parts and then make a lap joint and we can do nut and bolt fastening, even for riveting also you require a whole there for drilling is an indispensable operation, specifically for polymer matrix composite parts.

So, we will see, we will see each of the process that is highlighted today in our session, in our subsequent sessions. So, today will be an introductory session related to our secondary processing of polymer matrix composites. The, let us try to understand, I think the learners must have been able to understand or at least acknowledge the importance of

secondary processing of polymer composites at why secondary processing is required, because the parts, that we make using the primary processing technique, do have limitations in terms of part complexity. You cannot make a very complex part, using any standard manufacturing process for polymer matrix composites.

So, what is done, usually we divide the part into subparts, this sub parts are usually manufactured by anyone process, if it is a flat part, we can use compression molding, if it is a axisymmetric part long cylindrical shape, we can use filament winding process, if it is still longer and it is continuous very large length, we can go for pultrusion. Now, different parts can be manufactured using different manufacturing processes that we have already covered, but when the final product has to be assembled there, we require the assembly operations and for assembly operation, we require either using adhesive joining or using mechanical fasting or sometimes, we may use laser that other sources to induce heat in the specific area, where the joint has to be developed. So, that our polymer melts or at least, it goes beyond a glass transition temperature into a resinous reason, where we can make a joint.

So, all these types of processes, fall under the secondary processing of polymer matrix composites. So, now, we will try to see one by one that what are the important techniques of joining of polymer matrix composites, I think, I have given a very long introduction, today, related to our discussion, because this is important. Today, is a first session related to the secondary processing of polymer composites and therefore, it was important to highlight, the importance of these operations in context of the development of a composite product.

Now, we will see an ideal design having no joints, is not possible in the real word. Let us take a very complicated example of an aircraft. An aircraft cannot be directly made by a single process. So, the aircraft is always made, been different parts components assembly, sub assemblies, and then finally, we build up a part that finally, build upon these parts and finally, we get an aircraft.

So, it is not possible. So, an ideal design should have no joints, but it is not possible in the real world. If we take example of a human body, here also we will see there are so many joints. We have a knee joint, we have a ankle joint. So, we have different types of joints in our body also. So, naturally accruing body has also got number of joints.

Similarly, any product that we wish to develop will definitely have number of joints and those joining procedure or joint strength is an important criteria. If your joint is not having adequate strength, the structure will fail from the joint only. Now, you can very easily see that in our body also whenever there is some accidental fall or there is a problem, the most susceptible part of our body are the joints only.

So, therefore, the importance of joints cannot be undermined and therefore, we need to understand that, what is the importance of these joints in developing the polymer matrix composite products and now, we will try to understand that what are the specific processes that are used for processing of polymer composites, specifically related to joining operations. So, in order to manufacture and intricate composite product, several parts and components have to be joined together through various techniques.

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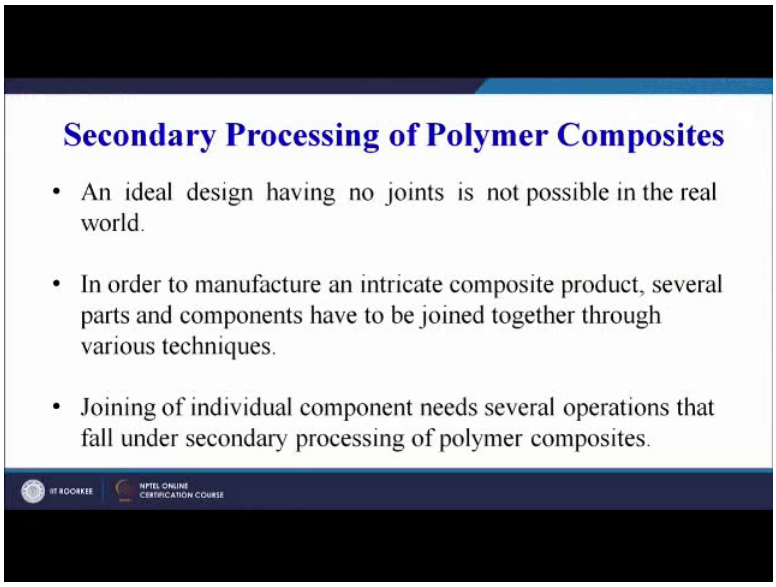

And that is the objective of our session to just have an overview of these techniques that are used for joining of polymer matrix composite parts, joining of individual components needs several operations that fall under the secondary processing of polymer composites.

So, secondary processing primarily will deal with the joining operations only and within joining, we will see that what are the additional operations. We have to carry in order to ensure a good quality joint between the 2 mating surfaces or between the 2 mating composite parts. So, let us try to understand one by one that what are the important techniques and as I have already explained, in our next sessions are, in our next session,

we will be focusing on each of these techniques in much more detail and try to understand that process specially in context of the composite materials, we are some of, you may be feeling the today's session is redundant session for you, because whatever techniques that we are going to cover are well known to all of you, but with time, you will see that these processes are modified, specially in context of the composite materials like all of you may be knowing welding of metals, but welding of metals, may not be directly applied to welding of plastics or polymer matrix composites, why because there are specific requirements, that have to be met in order to design a good quality joint. So, that is an important point that we have to take care.

So, first process most commonly used as you can see on your screen is the adhesive joining process.

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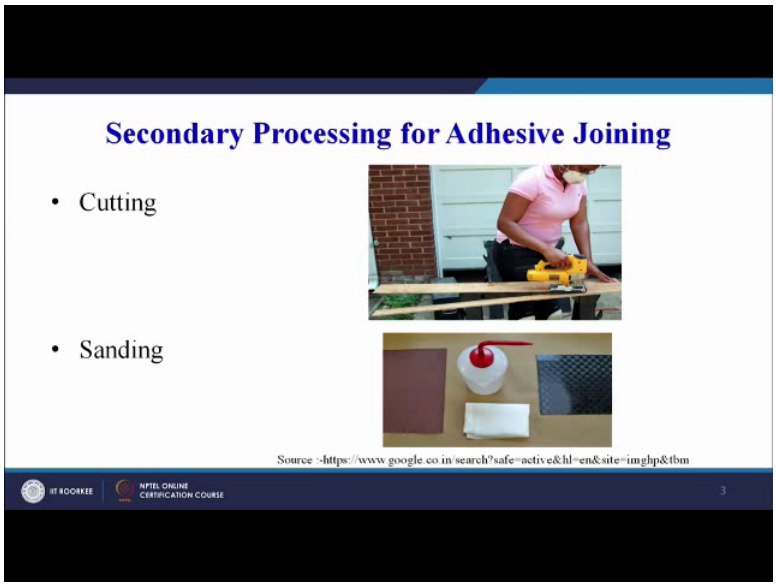

So, we have to first cut the parts, as per the dimension and then we have to do the sanding operation, may be that falls under the major category of edge preparation and we will see the surface preparation or edge preparation for joining in detail, when we will study adhesive joining. So, we are just going to highlight that, what are the 2 or three steps involved in a adhesive joining? The cut, the part, then we do the edge preparation, then application of adhesive on the adherent. So, this why we are trying to understand the steps so that the learner can relate to what we are studying. All of us do joining, using the

adhesive, if toy of our children, it breaks, what we do? We usually take a adhesive of any standard company and join the 2 parts together and these are the steps that we cover.

So, similar tap type of steps are used for joining of polymers and polymer composites. So, even the process is related to joining a polymers also, we are not today focusing specific value on polymer composites. In general sense, adhesive joining can be used both for polymers and polymer based composites. So, first is cutting of the part as per the required dimensions, designed dimensions, then edge preparation.

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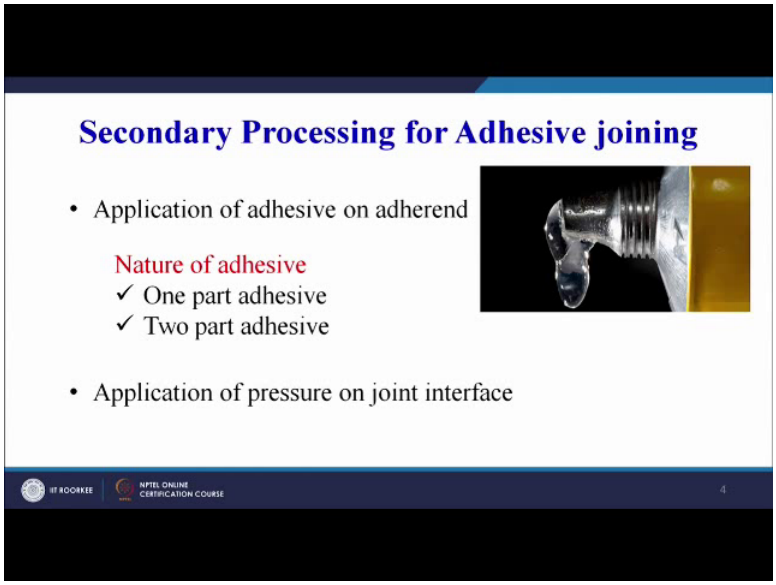

Then application of the adhesive on the adherent; adherent is the part that we want to join together. Suppose, these are the 2 parts that we want to join together, this is adherent one, this is a adherent 2 and they from a lap joint like this, in between we will apply a adhesive.

So, now adhesive can be one part adhesive or 2 part adhesive, specifically you will see that when you buy a product of a specific company, there are 2 tubes containing different chemicals, auto tubes containing different types of polymers or chemicals. So, why those 2 are used, that we will see when we will try to understand the adhesive joining in detail and I leave this as an assignment to you, because that is also a polymer and you know that curing of polymer is done. Why it is done and what are the ingredients? From there you can get the answer that why 2 part adhesive is used for the joining or adhesive joining of 2 plastic polymer or polymer composites part.

Application of pressure on joint interface. So, we have to first cut, then edge preparation, then application of a adhesive, then application of pressure on the interface. So, then finally, we will leave our joint for specific period of time, the time may vary depending upon the type of a adhesive that we have used and it may vary from 6 hours to 12 hours to even 24 hours and finally, we will get our joint that would be final joint, which can be used as a product.

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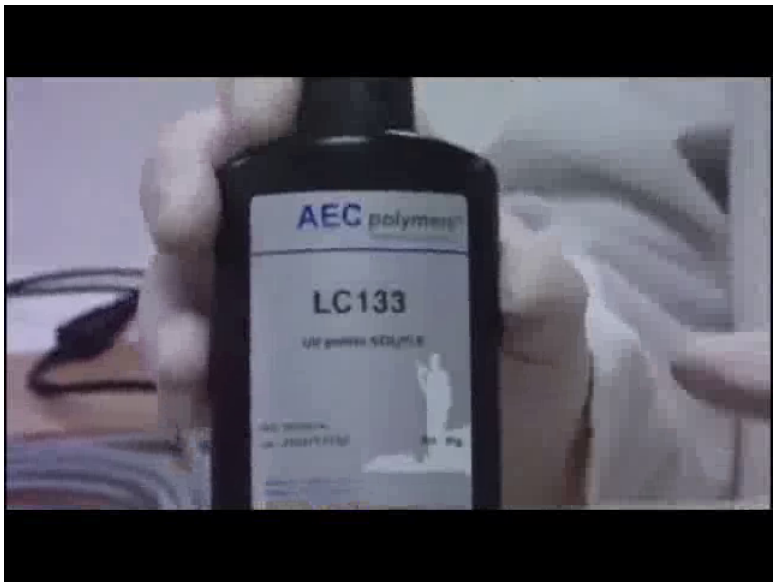

Now, let us try to understand this with the help of a video, very simple video, freely available on the YouTube. You can just have a look, joining of 2 adherent, this is the adhesive.

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This is the adherent number one, a application of a adhesive is being done. So, we have seen that there can be one part adhesive, 2 part adhesive and this is specifically our one part adhesive, the second adherent is being placed, the lap joint configuration.

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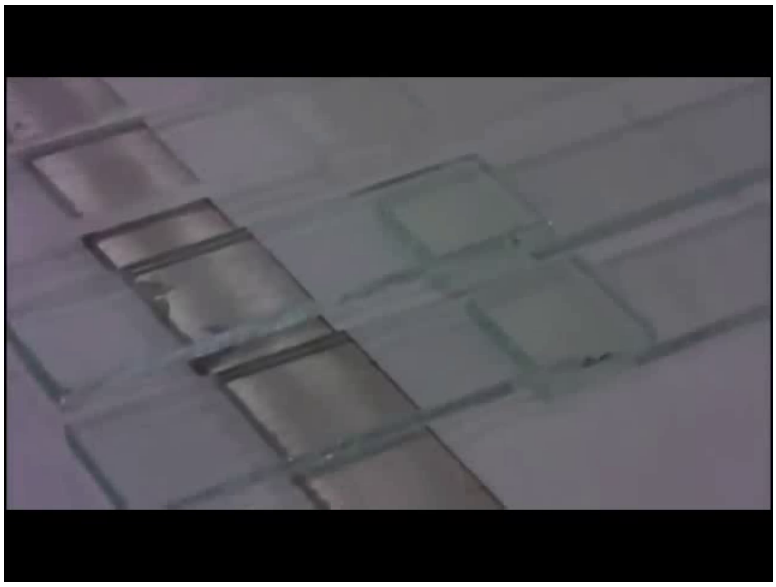

So, no edge preparation has been done here, directly application of adhesive and then the placing of the second adherent and then this is the application of heat.

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Which will help in the curing process of the polymer, which has been used for making this joint or has been used as an adhesive and the joint is ready. So, you can see that no pressure has been applied in this case, the 2 adherent have been taken in between, we have played an adhesive and after the adhesive has been applied, the curing has been done, using heat.

So, that is the basic most simplistic type of joining that has been done. Basically, the aim of showing this video was to just explain the nomenclature, we have used the word adherent. So, on one adherent, we have applied adhesive. This is a adhesive, then we second adherent and then with the heat, we have tried to cure the joint in some cases, you will see, we will apply the pressure also for curing as well as for consolidation purpose is. So, in this case no pressure has been applied.

So, different types of composites different types of polymers will require different types of joining techniques. So, one joining technique I think the most commonly used is the adhesive joining technique.

Then sometimes the adhesive joining technique may not be that relevant and may not be that successful also because of the limitations of adhesive joining, one of the limitations can be the low bond strength or low interfacial bond strength, due to the application of the adhesive. Therefore, we may go for nut and bolt type of fastening, usually we call

this type of fastening as a mechanical fastening technique. So, in mechanical joining we require the drilling of holes.

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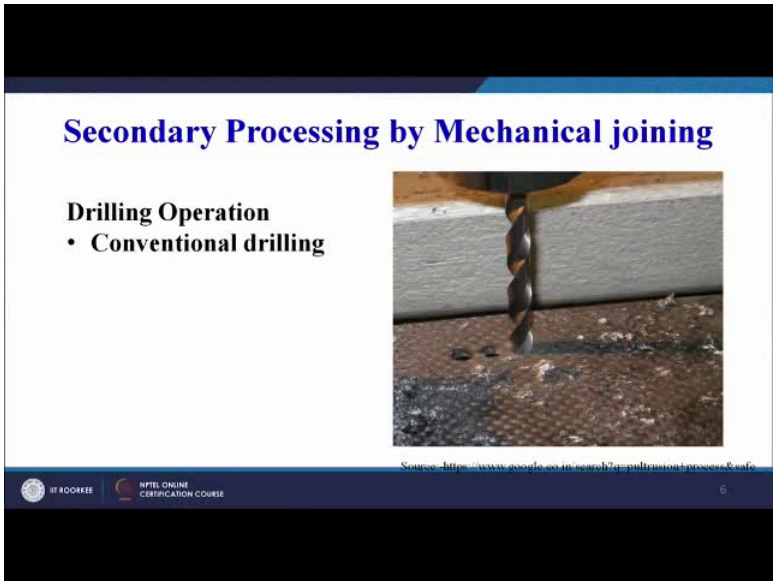

So, here we have a composite plate and drilling can be done, to generate a hole, for providing a site for doing the fastening operation.

Hole making by conventional drilling as was shown in the previous slide is a very challenging task. This one sentence is a very challenging task contains a complete list of problems encountered during the drilling of polymer matrix composites even you can try to make a hole inside a polymer or a plastic part. You will see that it is difficult the quality edge, quality and the dimensional stability or dimensional accuracy that we get is not very very good . So, therefore, making of holes in composites is a challenging task and therefore, we will address this with the help of few sessions dedicated towards, that what are the problem areas in making holes in composite parts, because when you are going to use this composite for specific applications and the application requires and nut and bolt type of fastening procedure, if you have to make a hole inside a composite, there will, there your life is going to be very challenging, specifically in the context of good quality holes that you would like to make in your composite part.

Researchers worldwide have tried to do away with the conventional drilling, they say when the tool and the composite part of the polymer composite part will come in contact, there is bound to be some damage happening to the polymer and the fiber agreed people

have tried to develop across. The word process is where the tool will not come in contact with the work piece that is our polymer composite. So, how that can be avoided using the process like vibratory assisted drilling.

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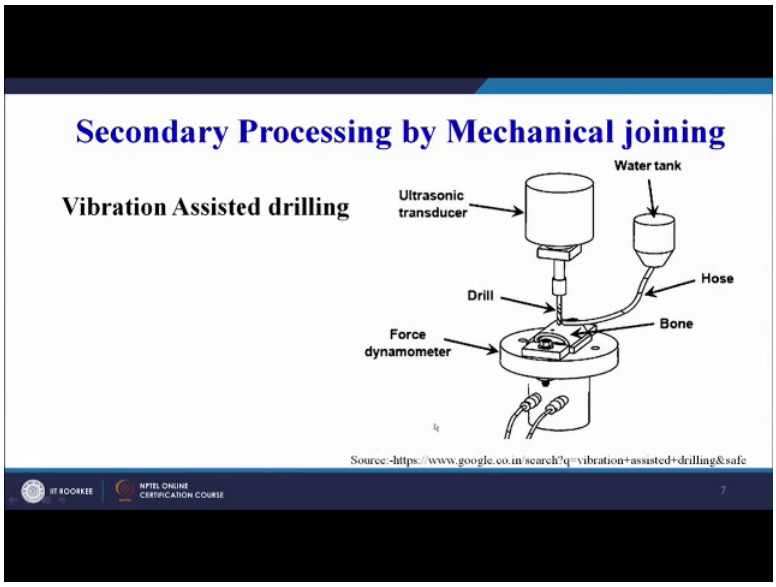

So, here on your screen, you can see this is the drill about, we have ultrasonic transducer, which will vibrate the drill at predefined frequency and then we have a force dynamometer, here to understand the difference.

Now this drill, without the ultrasonic transducer, if we are making a hole, it is conventional drilling, without the ultrasonic transducer. Now, edition of ultrasonic transducer giving vibration to the drill. We can have vibration assisted drilling. So, maybe, this process has been found out to be slightly better as compared to the force is generated. So, force is we can measure, using the force dynamo meter. So, as far as conventional drilling, the tool is indirect contact, with the work piece in conventional drilling, where as in vibratory assisted drilling tool will vibrate and it will sometimes, maybe in intermittent contact with the work piece and therefore, the forces that we get are usually lower, but the damage that way get in both the case is, that is an issue that requires attention and where we have to do the comparative analysis, that where we are getting less damage and under what circumstances we are getting more damage.

So, that we will try to understand in our subsequent sessions. So, vibratory assisted drilling is a modified version of conventional drilling and has been applied by

researchers worldwide to reduce or minimize the effect of drilling, induced damage in composite parts, then ultrasonic drilling is another drilling, procedure in which, in the, we have this, is a third process for hole making, the first process was conventional drilling, second one is vibration assisted drilling board is drilling. We are using the drilling tool for making a hole, but we are giving a vibration to the tool.

Now, here this is ultrasonic, the tool is vibrating, but it is not coming in contact with the work piece, there will be a abrasive slurry that will be between the tool and the work piece and tool will be heating, the adhesive particles in the slurry and the particles will go and hit the work piece and will try to remove the material by erosion process. So, ultrasonic drilling is another process, which has been applied, but one of the challenges for ultrasonic process is that, the work piece should be brittle in nature, for ductile work pieces is process, is not much suitable and we can see that in polymer matrix composite, the bulk is made by the polymer. Now, you can yourself imagine that it is difficult to use ultrasonic drilling, for making holes in polymer based composites or need polymer.

So, what are the challenges, how we can modify the process for making a hole in a polymer matrix composite, using the ultrasonic drilling process, that we are trying to understand in our subsequent sessions. So, today is the introductory session, just highlighting the process is which have been applied by researchers, engineers, scientists, worldwide in order to make good quality holes in polymer composites, then we can go for a punching operation, it has got, it is on limitation. So, that is another process, which can be used for making holes in composite parts.

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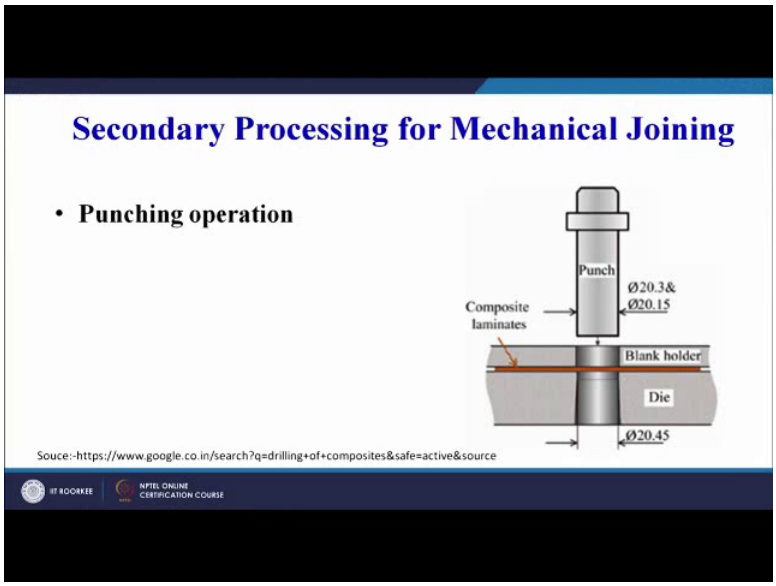

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Then we can do mechanical joining by mechanical fasting and riveting sometimes rivets, but this joining will also require holes in the composite part, one thing that we have not covered till now, the doubt may be coming to your minds also that why not to make a hole during the molding stage only, we have seen in number of processes and I think you can remember those processes in our processing of polymer parts, processing of polymer matrix composites, the processes that we have already covered, there are few process is where there is a provision, there is a advantage of putting our inserts at specific location, during the molding stage only. So, that is also possible that in many cases wherever it is

desirable and we can achieve that, we can put our inserts and then do complete, the molding process.

So, that we have a pre drilled hole or pre molded hole for our composite product, but it cannot be done in almost all situations, but for certain specific situations, during the molding also we can have the holes generated, during the primary processing technique or during the primary processing stage only. So, fastening and riveting also, may sometimes require making of holes in the composite parts.

Now, we can also the secondary processing by fusion bonding, sometimes we can use laser as a source of heat in fusion bonding. We have to join the 2 adherents together and at the joint interface. We may be requiring to have a, we may require to impinge or to expose this joint interface to some as form of energy, now that form of energy can be heat energy, it can be in terms of maybe the relative motion or friction between the 2 surfaces. So, the energy has to be given at that joint. So, that the joint takes place and here in this specific example shown on the screen, we are laser as a source of heat.

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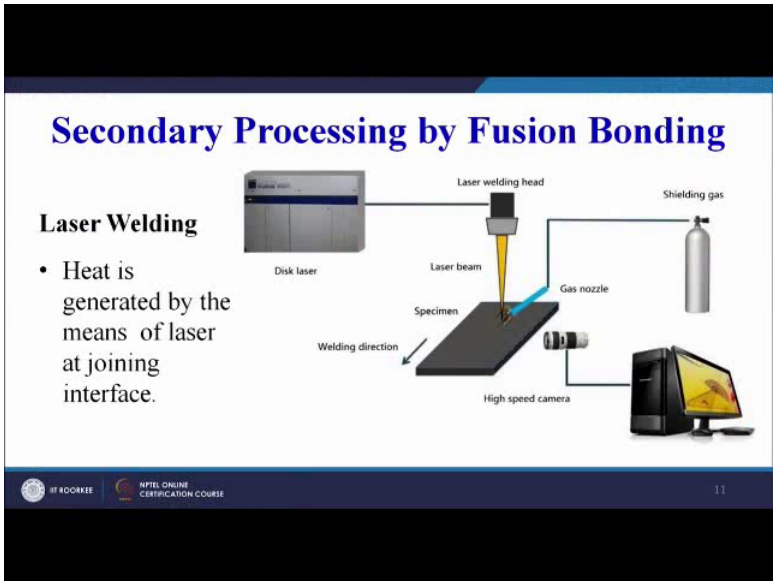

So, we can join the 2 polymer parts or 2 composite parts, made by polymer composites using laser welding, but with some specific precautions, the normal setup maybe, may not be possible to make a joint in polymers and polymer composite, but the modified laser beam setup can be used for making holes in the composites parts, for not, for

making holes, but for joining of the composite part by exposing the joint interface to the heat.

Now, the secondary processing by fusion bonding can also be done where ultrasonic welding can be done as I have told the 2 parts to be weld, it together are exposed to ultrasonic vibrations and because of this frequent motion of the 2 serve to joint interfaces, we can develop a joint. So, basically we have tried to understand. Today that what are the techniques tools that are used for joining of polymer parts or polymer matrix composite parts, the basic purpose of today's session was to introduce you, to you the basic concept of secondary processing, that we can make polymer or plastic parts, we can easily make polymer matrix composite parts, we know the process is that are used for making or processing of polymers. We know the processes, which are used for processing of polymer matrix composites, but when we have to join these parts together, what are the processes that have been used that processes we have tried to just list. Today, the individual mechanism of the process, the limitations of the process, the application areas of the process, the challenges for that process one by one, we will be covering in our subsequent sessions.

Thank you very much