Processing of Polymers and Polymer Composites

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Lecture – 36
Methods to Prevent Drilling Induced Damage

[FL] friends. Welcome to session 36, in our course on Processing of Polymers and Polymer Composites. In the last session we were discussing the secondary processing of composites that is polymer matrix composite materials, and if you see if we remember what we were covered in the previous session you may be remembering that we have covered that what are the different types of damage that takes place during the drilling of polymer matrix composites. And we have seen one summarized slide in which we have tried to cover that what are the methodologies adopted what are the techniques adopted in order to minimize the drilling induced damage.

Again and again I am emphasizing the importance of minimization. Till today if you have a composite material suppose you have a natural fiber reinforced polymer composites, suppose you use a bagasse fiber with a poly sorry polypropylene matrix to make a composite material I believe that none of the researchers will be able to tell you that you should make a hole using this drill at this cutting speed and at this feed rate that is the complexity of the problem. As the material changes your conditions also change your cutting speed or the optimal cutting speed will change your optimal feed rate will change, your optimal tool material will change, your optimal tool point geometry will change.

So, as soon as you change the fiber as soon as you change the matrix your conditions automatically change therefore, making holes in composite materials is a difficult task, but overall problems remains the same. In the last session we have seen that there is a damage that takes place around the hole and that is the biggest challenge and we have seen that we may get a peal up type of delamination we may get a push down type of delamination. Now, this delamination has to be controlled. We may get a circularity defect around the hole we may not get a exactly circular hole, we may get out of roundness we may get poor surface roughness around the hole wall.

So, all these things we need to control and how we can control all these types of damage we have seen that number of strategies have been adopted worldwide in order to minimize this type of damage. And today also we are going to see that what process modifications we can do in order to make holes that are of good quality. So, I am not clarifying or I am not establishing or I am not claiming that we will be able to make a clean cut good quality hole using any one of these techniques, but yes these techniques have certainly resulted in making holes which are better in quality as compared to the standard approach of conventional hole making that usually we call as the drilling of polymer composite.

So, today we will focus on slightly modifications or slightly modified methods of making holes in polymer composites. So, let us start our discussion by just having a brief review of the methods that have been used for avoiding the damage.

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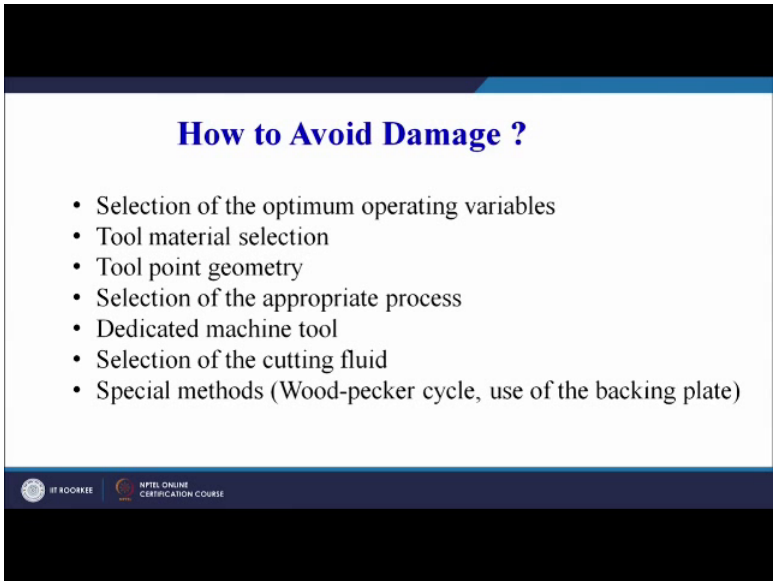

So, let us see our first slide that is first thing that we have covered in the previous session was how to avoid the damage. Now, that we have already covered in the previous session just I will not explain each point in detail, but we will just like to revise that what are the various methods techniques tools to avoid the damage.

The first is a selection of the optimal operating variables that is the cutting speed and the feed rate. If we select them properly our damage will be less. Tool material also we need to select we need to select a tool material which will give us good surface finish around

the hole. Tool point geometry I have shown in the previous slide to in the previous session towards the end of our session if you remember we have seen the thrust force signal varying with time, we have seen the torque signal varying with time and these signals will change with respect to the tool point geometry. So, the tool point geometry selection is also very very important because the tool geometry will influence, the forces the forces will subsequently influence the damage. So, we have to be very very judicious in selection of the tool point geometry.

Selection of the appropriate process today we will see that what are the modifications in the conventional drilling process which have been adopted worldwide and which have result it to minimizing the effect of damage in the holes. Then the dedicated machine tool we have seen that the machines that we use for making holes in metals may not be that applicable for making of holes in composite. So, we have to design develop machines which are specific to the concept or specific to the composite materials. Finally, we have to intelligently select the cutting fluid which may act as a coolant which may act also act as a lubricant.

Then finally, the last thing that is the improvisation the innovation in the machining processes which can lead to minimization of the damage and that innovation and improvisation the examples are the woodpecker cycle the use of the backing of plate and these are the two three techniques that we are going to cover today. And we will see that these techniques have definitely led to improvement in the quality of the hole in case of drilling of polymer composites.

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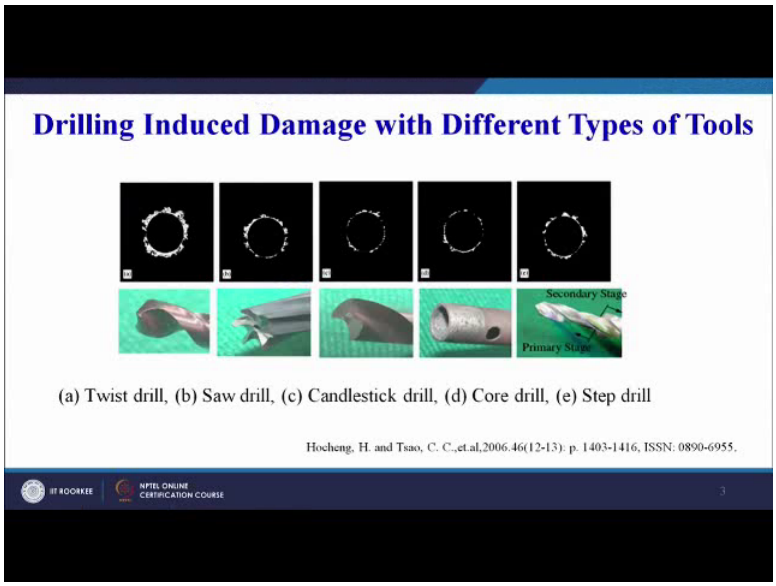

So, the first method to avoid the damage is the appropriate selection of the tool point geometry. Prior to that we need to judiciously select our cutting speed, we need to select the feed rate. So, those are the two important thing apart from that what we can control is the tool point geometry and here this slide has already been shown in the previous session also, but again I am emphasizing this slide again you can see this is the twist drill, saw drill, candlestick drill, core drill, step drill. So, different types of tool point geometries I can be used for making holes in different types of composite materials.

Must I mentioned that there was a research article published in American Machinist in the year 1987 published by Joseph Miller, J A miller and there in 1987 itself he investigated 17, 1 7 different drill point geometries and he proved that the drill point geometry plays a pivotal role plays a paramount role in defining the damage around the drilled hole. And here we are just showing only 5 different geometries which have been used and you can yourself see the central portion again I am emphasizing is the actual hole that we want to make and around the hole you see the damage.

And for twist drill which is the most commonly used drill for making holes in metal results in the maximum damage around the hole. Whereas the modified drill point geometries that is the saw drill the candlestick drill the core drill or the step drill all these drills are leading to lower damage or lower drilling induced damage or minimum drilling induced damage around the hole. So, here twist drill leads to a maximum damage and

may be in this if I have to visually examine I may say that the core drill is leading to the minimum damage around the hole.

But scientifically if we find out or quantify the damage around the hole there are number of tools and techniques one of the best technique to quantify the damage around the drilled holes can be the nondestructive dye penetrating. Then we can use a ultrasonic sees can also to see the area or observe the area around the drilled hole.

So, here just by visual examination I can suggest that twist drill leads to maximum damage and the core drill is leading to the minimum damage. So, which establishes the importance of tool point geometry as an important criteria for defining the damage around the drilled holes and that is why we should appropriately judiciously optimally intelligently select the drill point geometry. So, that the damage that we get around the drilled hole in case of polymer matrix composites is minimum. So, this is one of the important factors to be taken into account to minimize the damage.

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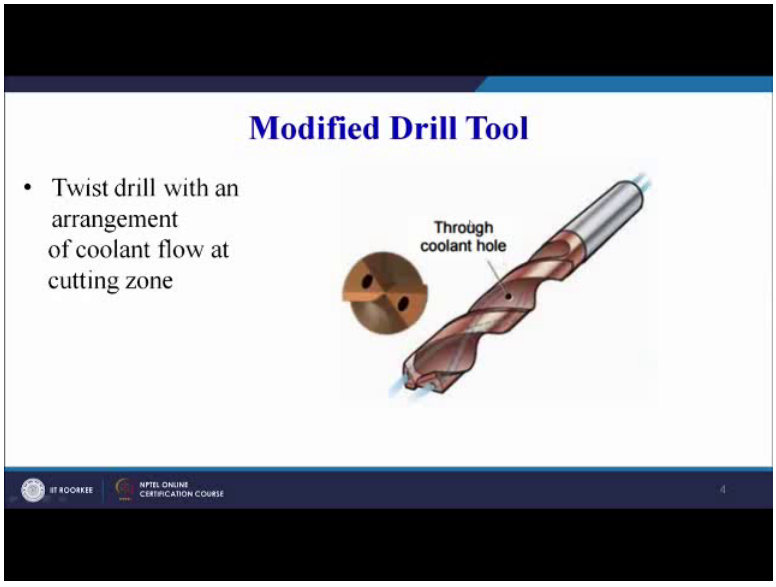

Then we can see the modified drill point geometry this is further modification here you can see there is a through coolant hole here these are the two holes. So, the twist drill with an arrangement of coolant flow at the cutting zone. So, different types of tools geometries can be investigated for optimizing the drilling performance of the polymer composites and this can be one drill.

As I have discussed in the previous session also that it is always not important to use the coolant or the lubricant of the cutting fluid in case of composite materials why the reasons I have explained in the previous session also. There can be may be may be reaction between the polymer and the lubricant or the cutting fluid which may be detrimental to the performance of the composite part with drilled hole during the in service condition. So, that needs to be taken into account that in all cases we may not like to use the cutting fluid. But yes in specific cases your cutting fluid is going to give us good performance modified drill point geometry that as shown on your screen can be helpful in improving the drilling performance during drilling of polymer matrix composites.

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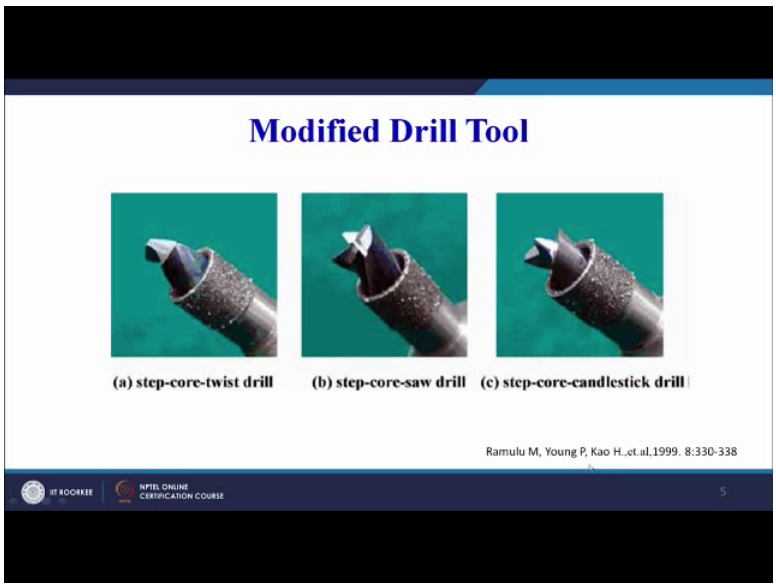

Similarly, we can see the other drill point geometries which have been investigated this is a article by M Ramulu, P Young and H Kao you can see the power article was published in 1999, that is maybe 18 years before and they have investigated three different drill point geometries and the names goes like this step core twist drill, step core saw drill, step core candlestick drill. So, different types of geometries have been tried in order to avoid the damage in the, damage around the hole in case of polymer matrix composites and more specifically fiber reinforced plastic.

So, by now, I think all of you all the learners all the students who are attending this course may be able to emphasize on the importance of drill point geometry as an

important criteria in defining the drilling performance in case of polymer matrix composite. Now, we will shift our attention slightly towards the processes that are the process modifications that can be done in order to minimize the damage.

Now, there are advanced techniques of hole making in polymer matrix composites. So, these are modifications in the conventional method only. Advanced techniques usually when we talk of advanced machining or advanced manufacturing method usually we go to the unconventional methods of machining. If you ask somebody what are the advanced machining method prompt is the reply that electric discharge machining, ultrasonic machining, electrochemical machining, plasma arc machining. So, here these processes are not advanced or these are not unconventional these are the modifications in the standard techniques only that is standard drilling operation is that you have a spindle you have a drill mounted on the spindle there is a fixture macular work piece there you make a hole this is the conventional hole making approach.

So, the process is that we are going to cover today maybe two or three processes we will cover will be the modifications of the conventional drilling method and subsequently we will shift our attention towards the non conventional hole making techniques also specially applied to hole making in polymer matrix composites.

So, let us quickly first look at the woodpecker cycle. Now, all of us have seen a woodpecker word even if we have not seen on our television sets or maybe on internet we may have seen that or we may have observed that how a woodpecker makes a hole in the tree. Now, the same concept can be used for making holes in composite materials. Now, here you can see peck drilling simulates the action of a woodpecker bird and the woodpecker bird how it makes a hole we will try to understand it with the help of a diagram, but the woodpecker cycle helps us to have better productivity. Now, productivity will be better if the damage around the hole is less and we are able to make more holes with better quality with minimum damage or try to minimize the rejection rate.

If you remember in last to last session I have emphasized that the rejection rate is to the tune of 50 percent in case of drilling of polymer matrix composite. So, if by choosing a modified method of hole making we are able to reduce this rejection rate that will always lead to the higher productivity. So, the productivity can be better if you use the peck

drilling method then better chip evacuation or better chip removal can be achieved using the peck drilling or the woodpecker drilling cycle.

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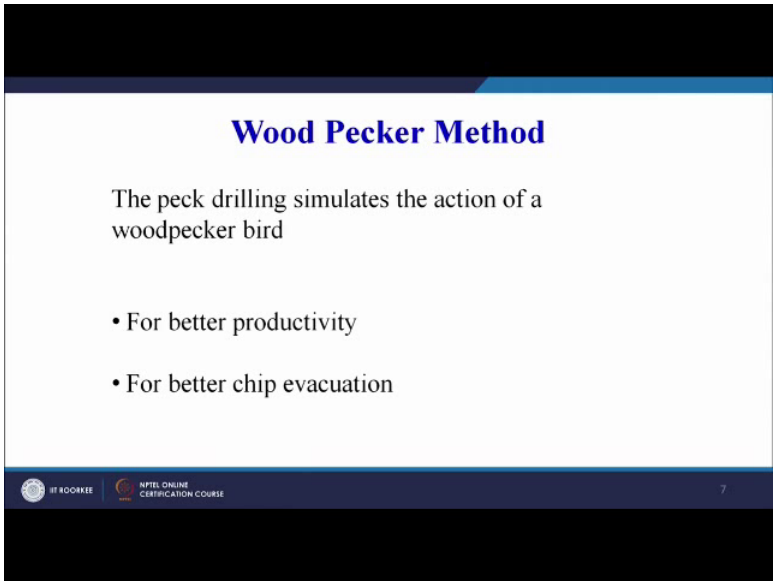

So, let us try to understand what is this method.

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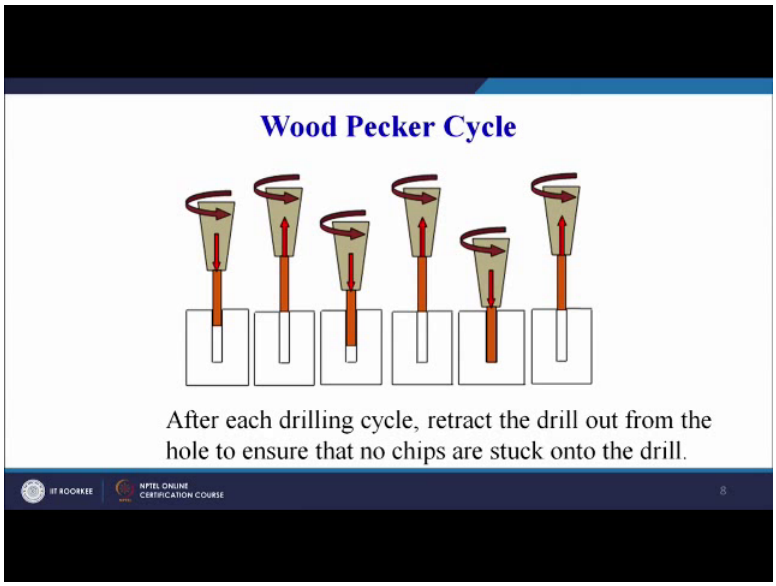

On your screen there is one diagram which explains the different stages of a peck drilling or woodpecker drilling cycle. So, this is our spindle it shows the rotation and this orange color represents our drill. At the start of the drilling cycle the drill enters into the laminate and then it is retracted back again it goes to the certain depth and again it is

retracted back then it goes to the full depth and then it is retracted back. So, in each retraction the chips are also removed. So, we are doing the drilling in three stages now.

The first stage is up to a particular depth and then the drill is retracted back and then up to a intermediate depth again the drill is retracted back and finally, we go to the complete depth of the hole and finally, the drill is retracted back. So, after each drilling cycle retract the drill out from the hole to ensure that no chips are stuck onto the drill. So, it this process leads to better chip evacuation of the chip removal.

Now, some of you may be wondering how this process can be better than the conventional drilling method because in conventional drilling the drill will come in contact with the work piece and then continuously it will move down and it will complete the hole and come out or exit from the other side if it is a through hole. And in that case the time taken will be less as compared to the woodpecker cycle because it is a single grow process.

And here we are going three times to make a hole of the equivalent depth. Now, that is a very valid question that how this process is better than the conventional drilling process. In conventional drilling process in most of the machines that we use we have a constant feed rate and when we have a constant feed rate in the beginning suppose I want to make a hole in a 10 millimeter thick plate or a 10 millimeter thick composite laminate as soon as I start to make a hole from the top I have fixed your feed rate. For example, it is zero point three millimeter per revolution. Now, the at this feed rate constant feed rate I am going down and I am generating a hole in the composite laminate. To the feed rate remains constant till the end I have made the hole, but the material that is under the drill keeps on reducing as and when the drill is moving down. So, towards the end of the hole making operation will lead to the delamination of the bottom layers and that constant feed rate is therefore, become a challenge.

Here in this case we can even manipulate the feed rate towards the last cycle towards the last entry of the drill we can manipulate we can change our feed rate. In conventional drilling also these days CNC machines are available in which we can write a program and we can maneuver we can manipulate our feed rate during the cycle or during the drilling cycle also, but may be previous maybe 15 20 30 years back the constant feed rate machines were most widely used and therefore, there was this problem, but today we can

program the machine in such a way that the feed rate follows a particular trajectory or the feed rate follows a particular cycle. So, that towards the end the feed rate is less in the beginning we have a high feed rate and towards the end we can have a low feed rate. So, that we are able to minimize the effect of push down type of delamination, but in this case the push down delamination will certainly be less as compared to the conventional drilling if we are using a constant feed rate setup or constant feed rate machine tool.

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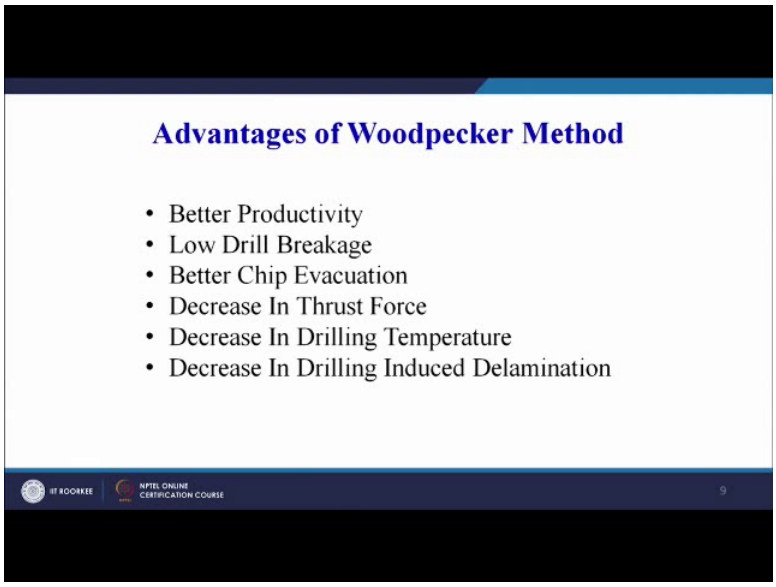

What can be the advantages of this woodpecker method? I will quickly read out the advantages that I have already explained better productivity, low drill breakage, better chip evacuation, decrease in the thrust force, decrease in the drilling temperature and decrease in the drilling induced delamination. Out of all if you ask me to choose one I will definitely pick the last one that is the decrease in the drilling induced delamination, there the damage that occurs around the hole is minimized if you use a woodpecker type of cycle as compared to the conventional drilling technique or conventional drilling method.

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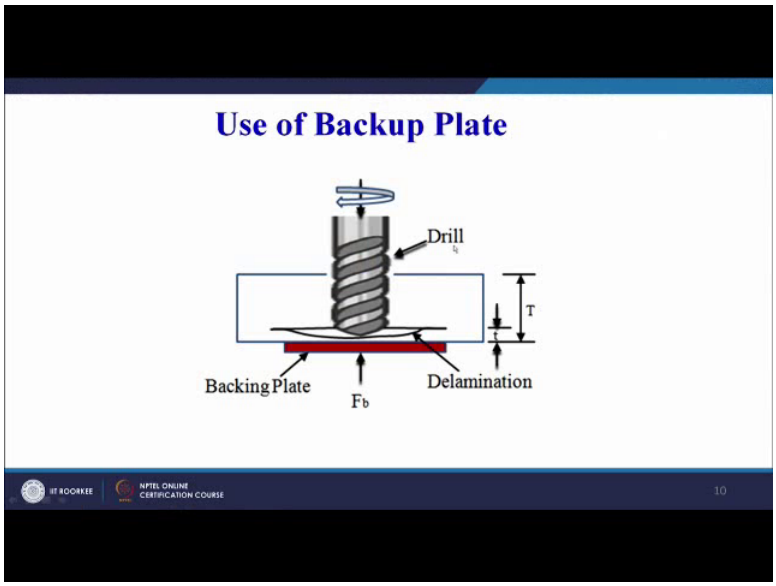

Let us now see the use of the backup plate on your screen there is a very simple diagram this is a drill not exactly representing a drill, but we can say it is a drill tool or a cutting tool our rotation is shown it is rotating and then it is making a hole. This is the complete the capital T is giving us the overall thickness of the laminate and the small t is representing the uncut thickness of the laminate. Now, this red color portion has been highlighted here this red color plate is our backing plate.

Now, if you have seen or if you remember in the previous session I have shown the pushdown type of delamination. Now, push down the type of delamination occurs towards the end of the laminate or towards the bottom layers of the laminate when the drill just exists from the hole.

Now, in this case when you put a backing up plate below the laminate the lower laminate will not get a chance to delaminate because they are supported from below with the help of a backing plate. And that support will not allow the d bonding of the bottom layers under the effect of thrust force and, so this backing up plate will help us to reduce the effect of push down type of delamination and this has proved successful in reducing the effect of push down type of delamination.

Now, some of you may be wondering when this technique has already been developed it has been found to be successful then while still people are conducting research in order to avoid or in order to minimize the push down type of delamination. The question is

very valid it is true that this technique would help us to minimize the effect of push down type of delamination, but in many situations, in many applications it is very difficult to place a backup plate in the exact location where the hole has to be made.

So, in that situations where you cannot have a backup plate you need to develop techniques, you need to develop methods which can help you avoid the drilling induced delamination without the use of the backup plate. So, therefore, this is possible this is helpful, but in specific application areas only and there are other areas where this backup type of plate will also not be that useful. But this is one method if possible we can use to avoid the push down type of delamination.

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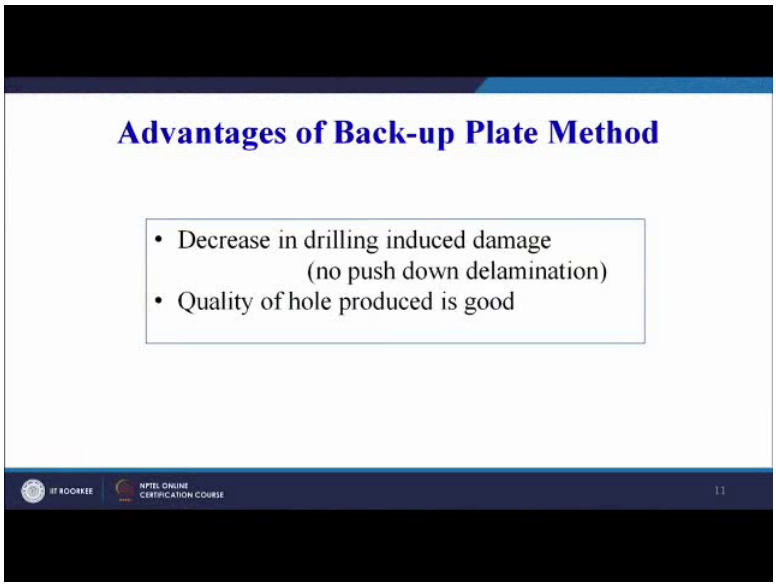

Now, what can be the advantages of the backup plate method? So, decrease in the drilling induced damage. So, that I have already told drilling induced is damage we are currently focusing on two important types of damage only that is the pileup type of delamination and the push down type of delamination.

So, this particular type of backup plate which is just placed, just at the bottom of over laminate during the drilling operation will help us avoid the push down type of delamination and the quality of the hole produced is also very very good.

Next method that we can use to reduce the damage is the helical feed method in helical feed method our grille will not go down along the axis of the drill, but it will revolve

around the axis of the hole. So, if we will, I will try to understand we will try to understand it I will try to explain it with the help of a diagram.

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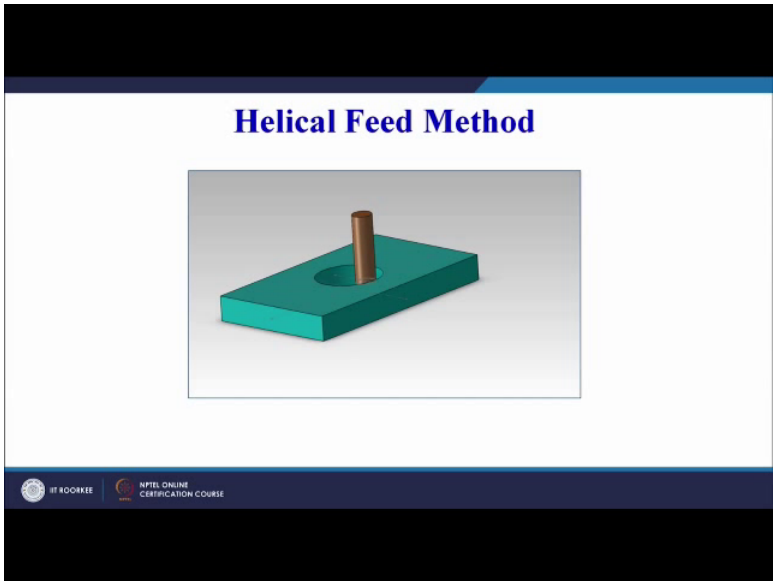

So, here you can see on your screen we want to make a circular hole. So, the drain is not moving down or the cutting tool is or the twist drill is not moving down along its axis, but it is moving down just in the helical method.

So, the feed is given helically. So, that the drill just also rotates and it moves down helically it does not move down straight.

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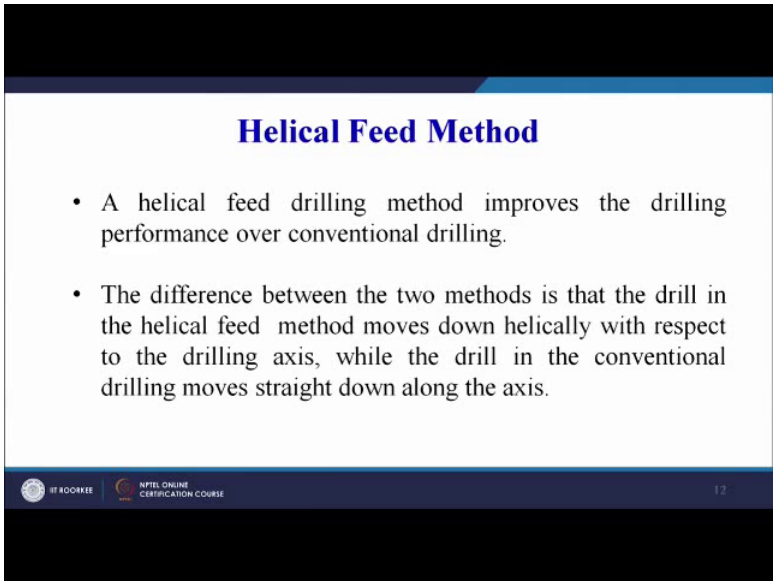

So, you can see a helical feed in helical feed drilling method it improves the drilling performance over the conventional drilling how it improves, what is the difference that has been clearly outlined in second point.

The difference between the two methods what are the two method the conventional method and the helical feed method. So, the difference between the two methods is that the drilling helical feed method moves down helically with respect to the drilling axis. So, it does not move down straight whereas, in case of conventional drilling it moves down straight along the axis.

Now, helically when it moves down it the thrust force is reduced and when the thrust force is reduced your push down delamination is definitely going to reduce, but the challenge is that you need to modify your machine tool accordingly. And if you see if you remember we have already covered in our title slide how to avoid damage that we need to develop dedicated machine tools for avoiding this damage and dedicated machine tool means that we need to modify sometimes our machine tool. In most of the drilling machines or drilling machine tools we have a constant movement of the drill feed rates are also almost constant and the drill moves along its axis down into the work piece material.

But in this case the drill has to move in a helical way just not along its axis and therefore, a dedicated machine is required for this purpose. But certainly it has been proved it has been experimentally evaluated it has been experimentally established that if you use a helical feed method of feeding that drill into the work piece it leads to less thrust force and helps us to avoid the drilling induced delaminations specifically the push down type of delamination.

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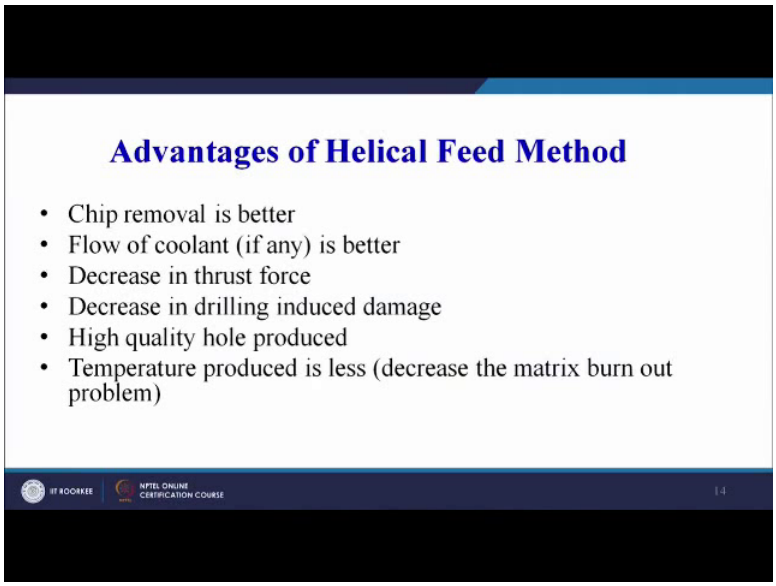

Now, what can be advantageous of the helical feed method? Chip removal is better because the chips get more space to come out from the hole area, flow of the coolant is better it can be very easily understood if you just focus on the diagram which are very schematic diagram that we have shown today very simple schematic, you can see that more area for the coolant to flow down. As I have already explained decrease in the thrust force that is, but obvious decrease in the drilling induced damage. So, when the force will decrease subsequently in almost 99 percent cases your damage will also be less. Quality of the hole produced is good and a temperature produced is less. So, the matrix burning is less and there is less temperature or heat buildup during the machining zone during the drilling of the polymer matrix composites.

So, with this I think we come or we conclude today's session and we have seen today that drilling induced damage is a very big problem it is an important issue we need to avoid the drilling induce damage and we have seen that there are three important methods which can be used for minimizing the effect of drilling induced damage in case of polymer matrix composites.

Now, what are these three methods? We have seen that we can use a helical feed method we have seen that we can place a backup plate just below the composite laminate during the drilling operation and the first method that we have seen that we can use a woodpecker cycle in order to avoid the drilling induced damage. So, all these three

methods the woodpecker cycle method, the backup plate method, the helical feed method all these are modifications in our conventional drilling methodology and these modifications have specifically helped us in order to make or in order to minimize drilling induced damage in case of polymer matrix composites.

In our next session we will focus our energy, we will focus our attention on understanding the unconventional roots or unconventional methods of making holes in composite materials, more specifically in polymer matrix composite materials

Thank you.