Manufacturing Guidelines for Product Design
Prof. Inderdeep Singh
Department of Mechanical and Industrial Engineering
Indian Institute of Technology-Roorkee

Lecture-35
Hole making: Guidelines

Namaskar friends, welcome to the last session of 7th week that is on hole making, so let us have a brief review of the 7th week that what we have discussed. We have tried to discuss the various joining methodologies, joining strategies that can be used for joining of plastics. And we have already finished 4 sessions in that, that is session number 31, 32, 33 and 34. So what have discussed?, we have discuss the induction welding of plastics.

We have discussed the ultrasonic welding of plastics, we have discuss the vibration as well as spin welding of plastics. We have also discussed the microwave heating mechanism or the use of microwave energy for joining of plastics. So basically why joining has become necessary during the product design that also we were able to highlight in the very first session that was session number 31.

We have seen that it is difficult to make larger products using the conventional processing techniques like injection molding or compression molding. And therefore we design the product in such a way that the product is manufactured in simpler parts. And then this simpler parts are assembled together using any one of the joining strategy strategies. And if we refer back even to week 6, in week 6 also we discussed or we reviewed the various joining strategies where we have seen that adhesive bonding is one technique.

We have seen welding, we have seen brazing, we have seen soldering, we have seen mechanical fastening, we have seen riveting. So all these techniques are used for the assembly of the simpler parts into the final product. Today as you can see on your screen the target is hole making, now why holes are required. Now you can see in the various joining methodologies that we have seen when you go for ultrasonic joining or you go for vibration assisted joining.

In those cases we have made flat surfaces only, but those are not the only type of joints that we usually make in case of products. In products different types of joints will be there many times the surfaces that are to be joined together will be aligned at an angle or there may be another specific requirements where the induction welding or the vibration welding or the ultrasonic welding may not be suitable.

So there in that case what is required we require to make holes in the parts, so that the mechanical fastening can be facilitated or the riveting can be facilitated. So for those situations where the other standard joining techniques such as adhesive joining, vibration joining, vibration welding, ultrasonic welding, induction welding. These processes are not suitable in those cases we will go for mechanical fastening or riveting with the help of threaded screws.

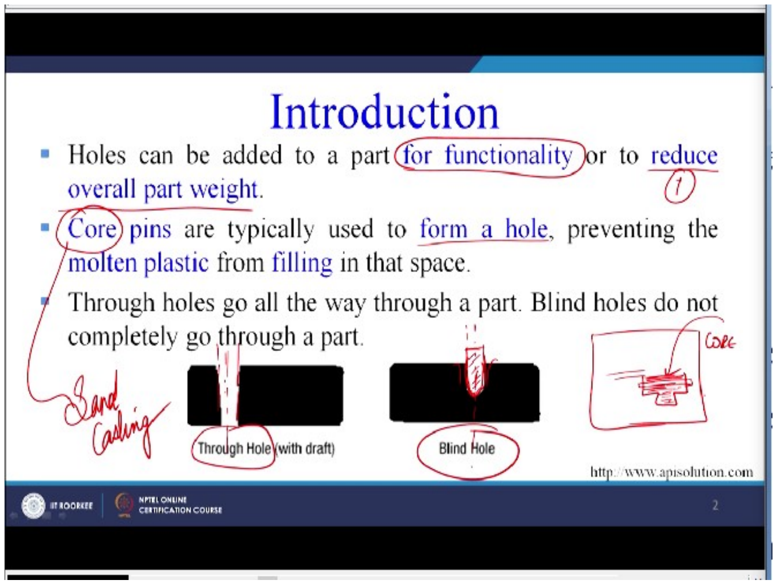
And in those cases we require a hole in the product that we are making or the parts of the product that have to be assembled together. And then these parts have to be designed accordingly where the holes must be located what must be the centre to centre distance between the hole what must be the diameter of the hole in context of the thickness of sheet that we are making. So all those things have to be kept in mind.

When we are designing the product which is going to have different parts which are going to be joined using the mechanical fastening technique using the threaded fasteners. So, that is basically the purpose of this lecture where we are trying to understand that how hole making must be accomplished in metals as well as in non metals. So, whatever examples we have taken some of them maybe relevant for thermoplastics, some of them maybe relevant for the metals.

Now let us start our discussion and try to understand that importance of hole making during the product design stage. Now during the initial introduction that we have, we have already established the importance of hole making and the overall summary of this week. Because today is the last session for this week that is week number 7, so why week number 7 has been designed I have been able to highlight that whenever the complex geometries of the products have to be processed.

The joining becomes inevitable and for joining different techniques have to be developed depending upon the raw material, depending upon the material with which the product is going to be made. And based on that hole making also is one of the important strategies which will facilitate the mechanical fastening of parts. So that is the overall summary of this week and the last topic is hole making.

(Refer Slide Time: 05:31)



Now holes can be added to a part for functionality or to reduce the overall part weight. Now 2 things are there. These are additional things whatever I have told in the introductory part that states but that establishes the importance of hole making only for fastening purposes. But sometimes we may create holes in the product to make it lightweight also as we can see it is mentioned here. Sometimes holes may be required in the part to reduce the weight of the part also holes can be added to a part for a functionality.

So some function this holes will provide, sometimes we may require holes for maybe pushing in water or maybe for as a coolant we need to push water or some other oil into the part or the products. So in that case also holes may become inevitable or the holes may be used for that purpose. So depending upon the requirement we will make the holes in the product and most importantly the holes made for fastening purposes.

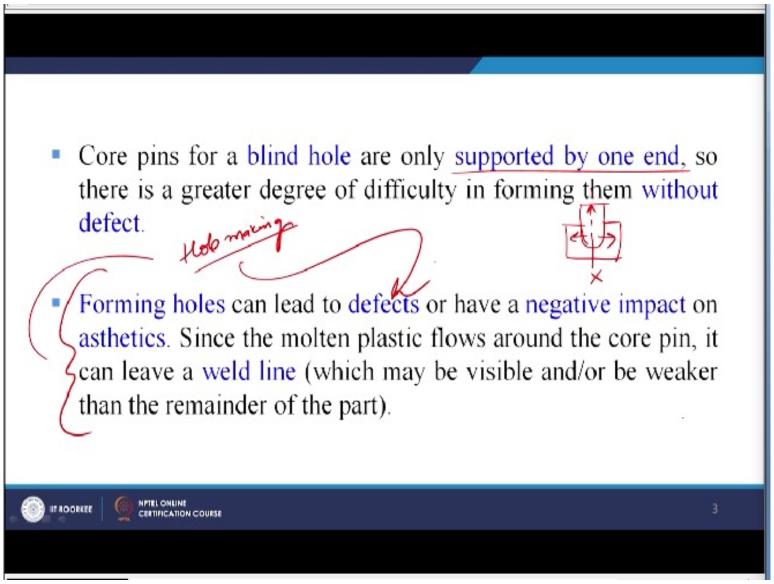
Now the holes can be made core pins, now core is a important word which we usually associate with the sand casting process and all of you know why the cores are used. So core pins are typically used to form a hole, so if you remember in case of sand casting also cores are used. So, very quickly maybe if I can draw a diagram of a mold cavity and if we want to require a hole here. We will place a core like this and we will have the core pins here.

So, this is basically a core which is placed inside the mold cavity in sand casting it would produce the and this is the place which will be filled by the metal. So we will have a core inside in order to have a through hold inside the casting. So similarly we can place a core here also and produce this holes. Similarly a core can be placed here and this hole can be produced. So, core pins are typically used to form a hole preventing the molten plastic from filling in that space.

Now suppose at this place if we have placed a core maybe of this much size. It will not allow the molten plastic to fill this area. Because this is already filled with cores, so molten plastic will flow around and fill the other area and we will get a hole here in the plastic after the solidification process. So, through holes go all the way this is the example of a through hole, through holes go all the way through the part, blind holes do not completely go through a part just a classification.

This is through hole and this is the blind hole because it is not going all through the part. So different types of holes can be made here we are taking an example of a plastic material we can create a through hole in a plastic with the help of a core pin or we can make a blind hole in a plastic product using the core pin. Now core pins from for a blind hole or only supported by one end.

(Refer Slide Time: 08:51)



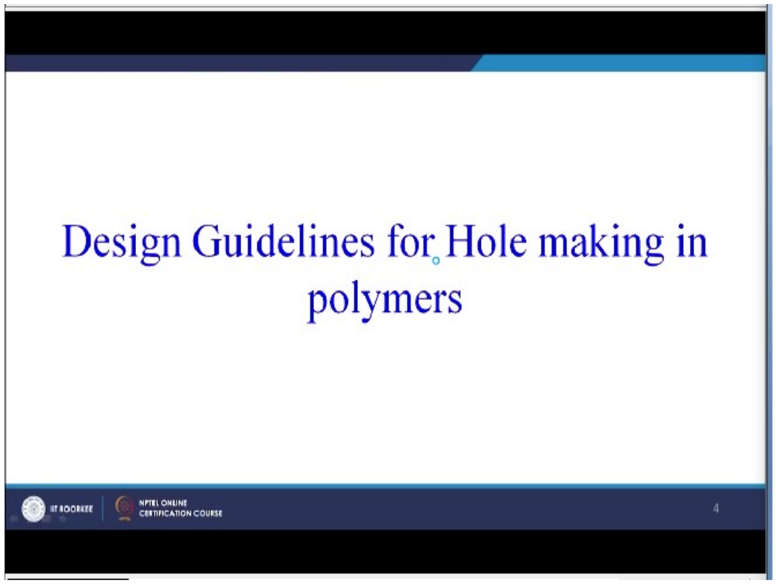
So, here we can see if we go back to the previous slide this type of core pin can be supported on both sides where as this core pin can only be supported on one side. So, therefore we can see that core pins for blind hole are only supported by one side. So here also again the diagram can be made this is a hole that we want to create, so this is the blind hole. So, the core pin will only be supported on this side, there is no support to the core pin on this side supported by one end.

So there is a greater degree of difficulty informing them without the defects, so there are chances that the core pin may get deflected in one of the directions and we may not be able to produce a good quality hole. So forming holes can leads to defects or have a negative impact on the aesthetics. So we may not be able to produce good quality holes in plastics using the core pins since the molten season plastic flows around the core pin.

It can leave a weld line which may be visible and or be weaker than the remainder of the part. So this is clearly highlighting that hole making in plastics is a challenging task why because of the defects that may be produced. So we have to be careful and we have to see that how we can make a good quality hole in a plastic part using the standard approaches. If we are not able to use the standard approach such as the use of a core pin.

We may have to go for the advanced techniques for making holes in the plastic parts. Now what are the design guidelines for hole making.

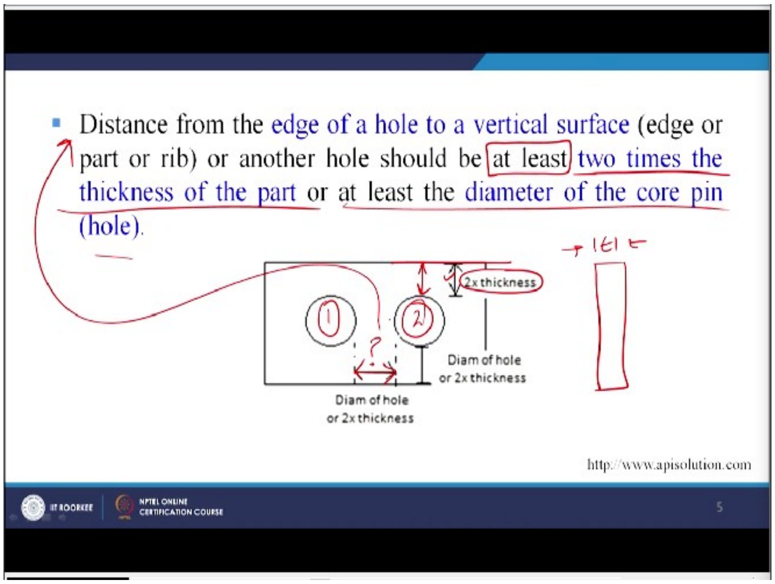
(Refer Slide Time: 10:30)



We have and try to understand that what are the techniques we have just one technique we have been able to review that is placing a core inside the mold. So, that the molten plastic will fill all the area except where the core pin is placed and when you take out the core pin it will create a hole after the solidification of the plastics. So you will take out the core pin after the molten plastic has already solidified.

So, it will create a cavity which will be on a hole, the hole can be through hole or it can be blind hole. Now what are the things or guidelines that we must keep in mind when we are making holes either in plastics or in metals.

(Refer Slide Time: 11:14)

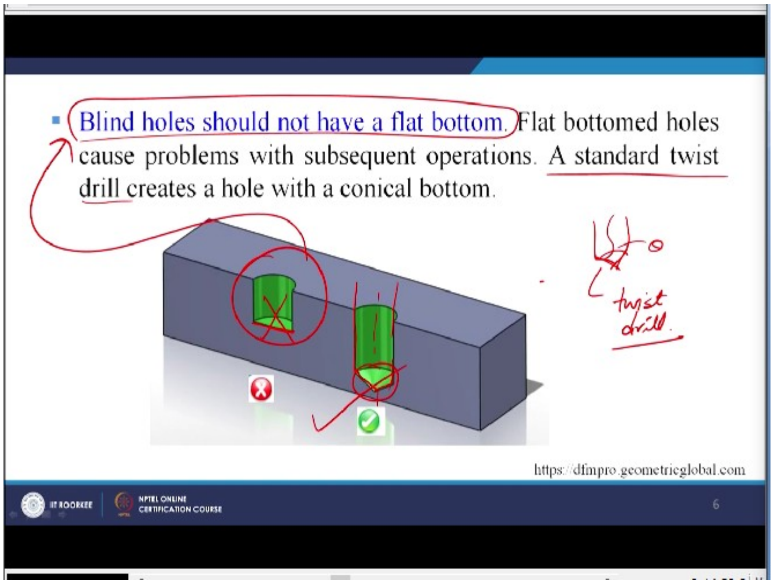


So, let us see now when one of the important thing is the distance between the holes, now this is our first hole this is our second hole what must be the distance?. So, this distance is clearly marked here what must this distance be?. Now this distance is clearly mentioned in the sentence here now how that distance we must decide distance from the edge of the hole. Now here this is the edge of the hole, this distance or we can say this distance already marked here.

So the distance from the edge of the hole to a vertical surface or edge or part or rib or another hole should be at least 2 times very very important at least 2 times the thickness of the part at least 2 times the thickness. So, whatever is the thickness if we say this is our plate in which we want to make the hole. This will certainly have certain thickness. So if we say that this is the thickness of this plate and we mark it by t.

So, this from the edge of the hole to the vertical surface must be 2 time the thickness or the distance between the 2 holes must be at least the diameter of the core pin diameter of the hole or 2 times the thickness. So, whatever is the diameter of the hole that distance must be there in between or it must be twice the thickness of the sheet which I have are the plate which I have already shown that is 2 times of t. So that is the guideline related to the distance of the hole from the edge and the distance between the 2 holes.

(Refer Slide Time: 12:57)

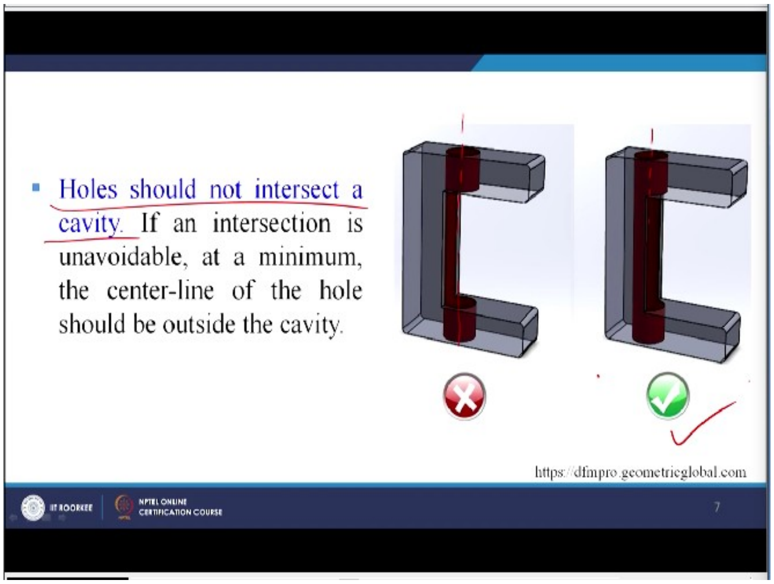


This is the very important guidelines specially use for in case of metals, blind holes should not have a flat bottom. This is a example of a blind hole and it is showing of flat bottom here is not advisable, it must have a bottom surface like this. Why because flat-bottomed holes cause problems with subsequent operations a standard twist drill. It is something like this, a standard twist drill this is a point angle theta

So, the standard twist drill creates hole with a conical bottom, so if this drill goes inside it will definitely create a hole with a conical bottom. So we must not specify a flat bottomed blind hole in case of our parts where the hole has to be done in the blind manner, especially in case of blind hole flat bottoms may not be specified. We can specify a conical bottom and therefore it is the right way of producing a hole inside a plate or inside a thick plate using the twist drill.

We are the cone or the bottom is conical in nature which is corresponding to this geometrical feature of the twist drill. So, this is another guideline which must be kept in mind.

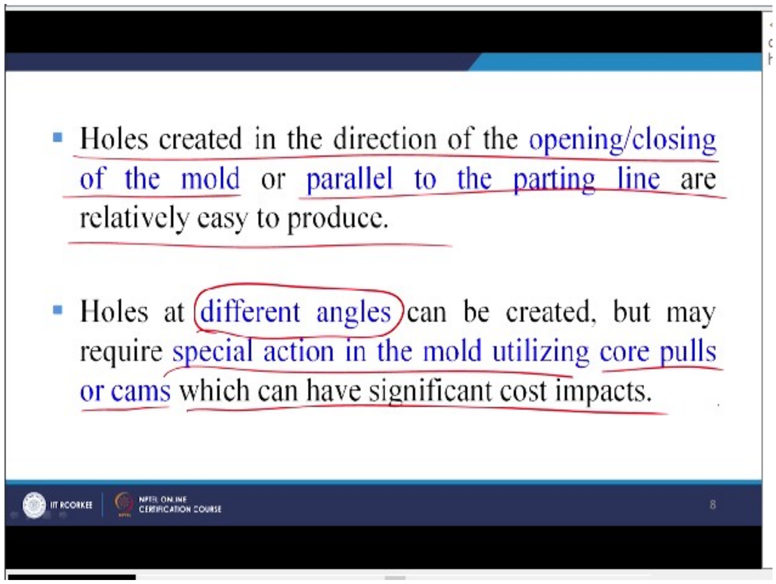
(Refer Slide Time: 14:31)



This is another guideline third guideline holes should not intersect a cavity. So, this is also very very important here there is a cavity here. The holes must not intersect a cavity which is very important, if an intersection is unavoidable many times this is not because here the hole is intersecting a cavity it is not recommended. So, if an intersection is unavoidable at a minimum a the central line of the hole should be outside the cavity.

So, if there is a cavity here the centre line must be outside the cavity. So, that must be taken into account, so this is the right way of producing a hole where it is intersecting a cavity. The central line should be if it is unavoidable the central Line of the hole should be outside the cavity that must be taken into account.

(Refer Slide Time: 15:24)



Holes created in the direction of the opening or closing of the mold, now suppose we are producing a hole in a process called maybe die casting oh in case of metals or injection molding in case of plastics. Now the 2 die house are the mold half will close to each other. So, when they are closing it is possible to create a hole along the direction of opening and closing. So, holes created in the direction of the opening closing of the mold are parallel to the parting line are relatively easy to produce.

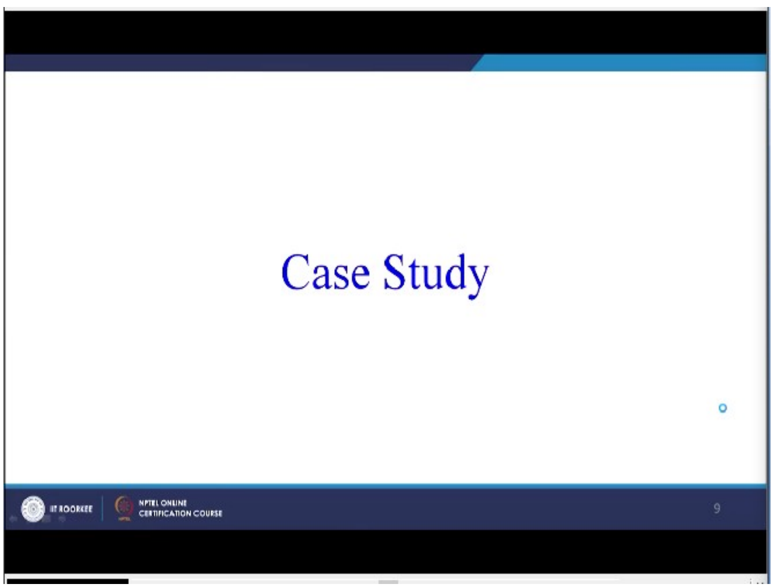
Suppose this is the opening and closing direction, one will be of course I must not show both moving one will be stationary another one is moving and closing the mold. So, this is the direction of opening and closing of the mold, so it is easy to make a hole in this direction or suppose we assume this is my parting line. So the 2 mold half are closing like this, so along this direction also it is easier make the hole along the or parallel to the parting line relatively easier to produce.

Here also there will be a maybe difference in the relative is may be along this direction it is better or along this direction it is better. But if the it is perpendicular direction this direction and this direction relatively better as compared to angular holes that may be required in some of the products. So holes created in the direction of the opening closing of the mold or parallel to the parting line are relatively easy to produce.

But holes that different angles which I have already highlighted holes at different angles can be created, but may require special action in the mold utilizing core pulls or cams which can have significant cost impacts. So special requirements, special requisites are there when angular holes have to be made. We have to may be design the cams in such a way that we are able to produce a conical hole or maybe angular hole while making the product.

So, maybe when we are designing our product we have to specify a hole for a specific purpose we must take into account the difficulties encountered in producing the angular holes in the product, always we must try to specify the holes in the direction that is either opening or closing of the mold or maybe along the parting line. Though those are easier to produce angular holes are difficult to produce required special as a requirements or special equipments or special tools.

(Refer Slide Time: 18:15)

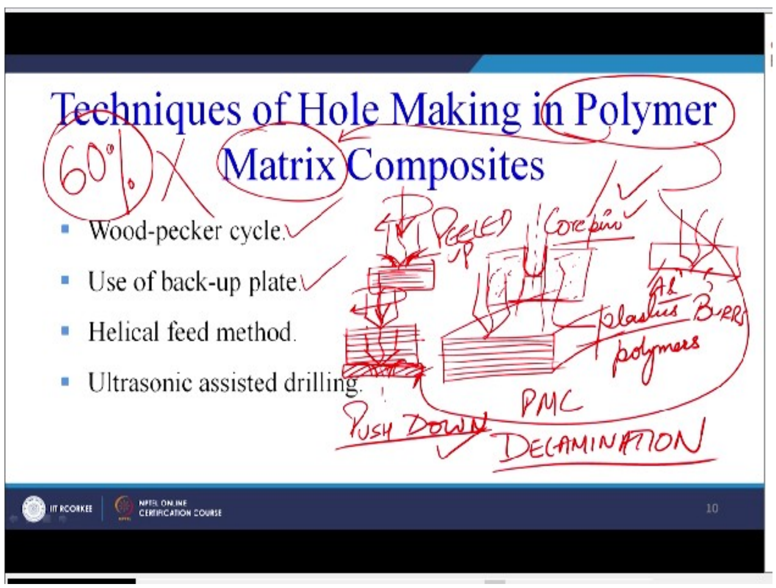


And therefore must be avoided, now let us take a case study of hole making now we know there other guidelines also related to hole making. But we have to make a comprehensive case that what are the important things that we must keep in mind when we are doing the operation of hole making in different types of materials. Now this is a case study related to hole making in a special class of materials which we have already discussed during our week 2nd that is engineering materials.

In second week our focus was an Engineering materials and we have discussed a special category of materials which are called as the composite materials. So, we have seen at least 3 or 4 specific guidelines which must be kept in mind whenever we are making holes or when we are specifying holes in our product design. And suppose we have to make holes in our product which are being used for assembly purpose or fastening purpose or for reducing the weight of the part or for any other purpose or for improving the functionality of the part.

When holes become in inevitable we can go for go for specific strategies for making the holes and here we are going for a specific material which is basically a composite material. Now what are the techniques of hole making in polymer matrix composites.

(Refer Slide Time: 19:30)



So, in polymers we have already seen that if there is a plastic part we can make through hole using a core pin. In today's class only we have seen that or we can make a blind hole were are this is also a part of this thing. We can make a blind hole again using a core pin and there can be certain defects that may take place during making a holes in plastics or we can say polymers. But when we talk about the polymer matrix composites, in that case there will be fibres also along with the polymer.

So which makes the process even more difficult, also in polymer matrix composites many times we make them in the form of layers also. So let us take an example, so this is a layered composite we are seeing only one view of this. This can maybe go in this direction also like this, suppose we want to make a hole in this, in this laminate. So once the material is drilled there are chances that the layers that are there in the composite may try to peel up like this.

When the drill is rotating also and it is going down also, so there are chances of layers getting peeled up here, that is called peel type of de-lamination and subsequently these are the layers of the fibres which are reinforcing the plastic or the polymer which is already. So, this is a polymer matrix composite, so again you can see the drill is making a hole it is going down. It is rotating also, so when it goes down suppose it reaches this point. There are chances that the bottom layers may open up.

This is again a form of de-lamination when the drill is just at the exit. So, this type of de-lamination is called the push down type of de-lamination, so we can have a peel up type of de-lamination, we can have push down type of de-lamination and specially even if we are making a hole in aluminium plate also. There are chances of formation of different types of burrs, so burr formation is also an issue in metals.

Similarly in polymers and polymer composite there are chances of de-lamination, in polymers we can call it as burr, in case of polymer matrix composites where we have layers of fibres there are chances of pushdown type of de-lamination. So I will write the word because it is a very common word which is used in case of polymer matrix composites de-lamination. So at the entry of the drill inside the composite when we are trying to make a hole.

You will have a peel up type of de-lamination at the entrance at the entry and at the exit you will have a push down type of de-lamination. So both are dangerous, both have to be avoided and there are data available where 60% is the rejection rate for the composites. So, when you make holes 60% of the holes are rejected why because either the push down type of de-lamination takes place or the peel up type of de-lamination will take place.

And the whole quality will be very poor, so the fibres will also come out sometimes we call it a fibre pull out. Sometimes a lot of heat is generated matrix burning matrix is a polymer in this case, so as the name suggest polymer matrix composites of polymer is a matrix. So, polymer may burn at very high temperature at very high speed and feed rate. So lot of problems are there when you try to make a hole in a composite materials.

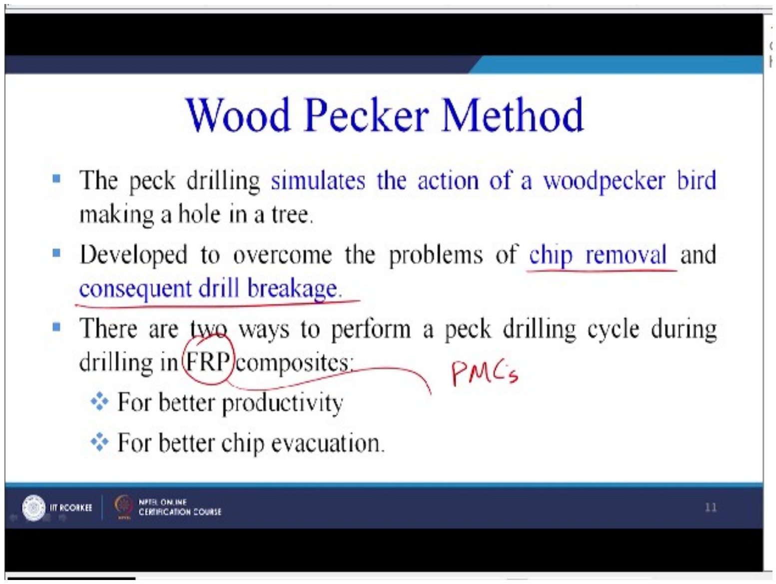
And these days composites are being used not only in aircraft industry they are being used in automotive industry also. They are being used in sports industry also, they are being used in marine industry also. So, therefore when we are proposing the use of a polymer matrix composite or fibre reinforced plastic, in any product we need to understand that if a hole has to be making. So all these things whatever I have explained or very serious issues and have to take into account.

But the picture is not that sad it is very rosy why because number of strategies have been developed by the researchers worldwide to mitigate to minimize the effect of this type of damage that takes place during hole making in the polymer composite parts. Now what are the strategies which have been developed some of the strategies are wood-pecker cycle. We will see them with the help of a diagram, use of a back-up plate maybe we can put a backup plate here which will not allow the push down type of de-lamination to take place.

Helical feed method is another method which has been device, ultrasonic assisted drilling as we have seen in this week only ultrasonic welding process. Similarly ultrasonic frequency can be used or vibrations can be given to the drill in order to make the drilling force is less. So that lesser damages produced, so let us quickly see each one of this with the help of a diagram.

But major emphasis of developing all these strategy is to reduce the damage that takes place during hole making in polymer matrix composites which is a special type of material which is used for aircraft industry. But now it is being used for a lot of other applications also. Now first let us take example of a woodpecker cycle.

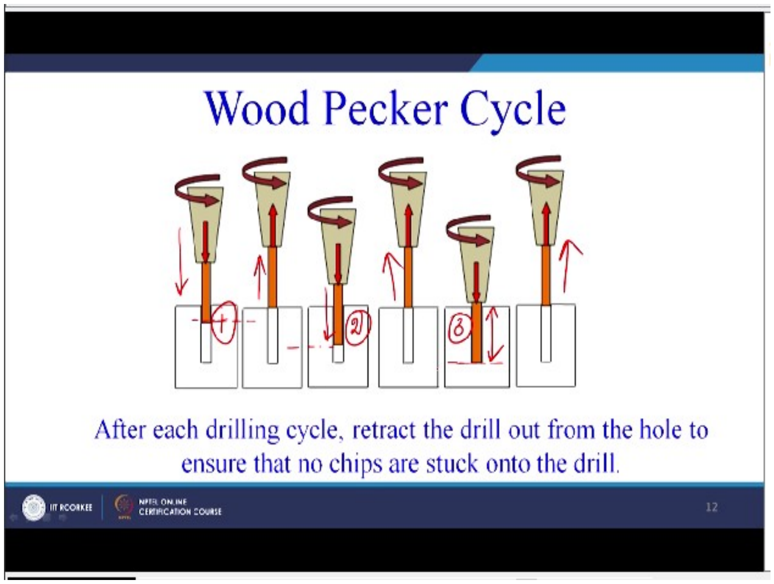
(Refer Slide Time: 25:43)



The peck drilling stimulates the action of a woodpecker bird making a hole in a tree, we will try to understand this with the help of a picture or a diagram. So, you all of you may have seen a wood pecker how it makes a hole in a tree. So it goes one step at a time, so maybe step by step by step it creates a hole. So, the peck drilling is the similar action only developed to overcome the problems of chip removal.

So if you do it step by step chips can be easily evacuated and consequently the drilled damage is also or the drill breakage is also minimize. There are 2 ways to perform peck drilling cycle during the drilling in FRP composites, so FRP another name of polymer matrix composites. So why we do wood peck drilling for better productivity for better chip evacuation.

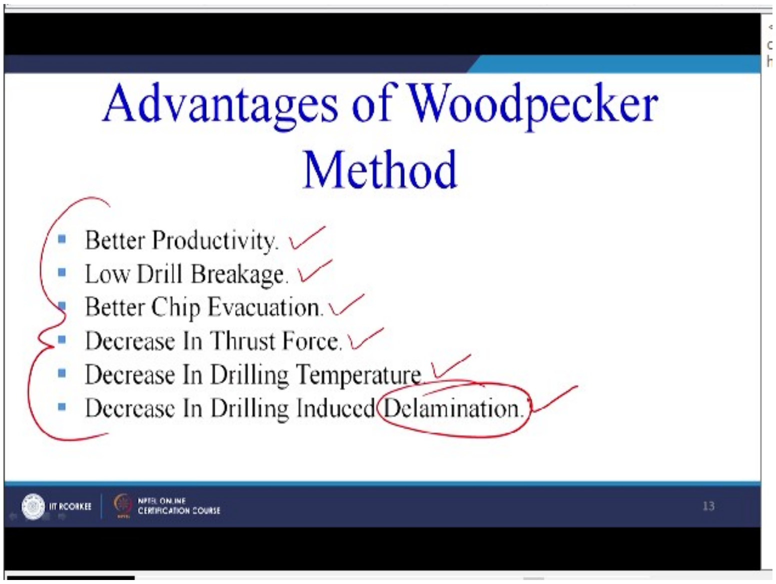
(Refer Slide Time: 26:37)



Now this is the wood pecker cycle you can see here the drill first goes down makes a hole till this point then it comes back. Then it again goes down up to this depth, so initially it goes up to this depth then it goes up to this depth. Then again it comes out then it further goes down the depth and then it comes out. So we can see the hole this is a total depth of the hole which has been produced. But it has been produced in the third step this is step one this is step 2 and this is step 3.

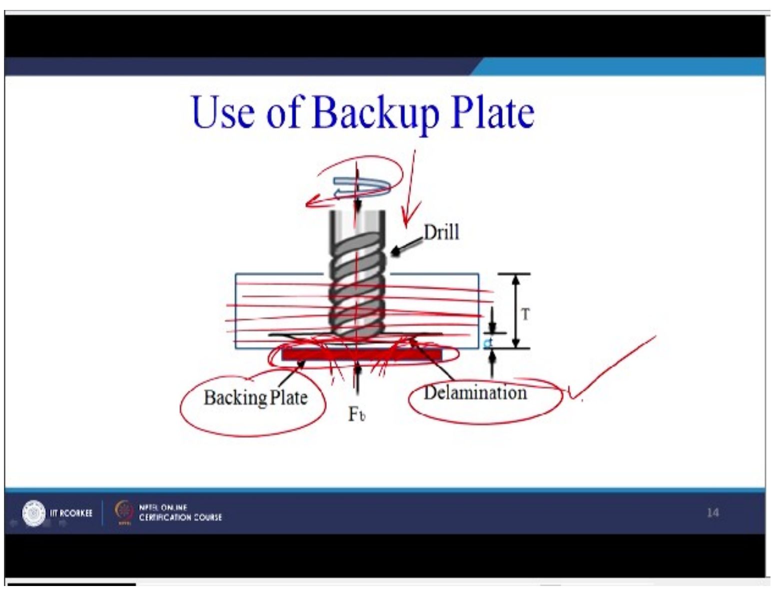
So we go inside then we come back again to a next depth level and then come back. After each drilling cycle retract the drill out from the hole to ensure that no chips are stuck on to the drill. So this is one approach which has been found to be applicable especially in case of very thick composite parts are very composite laminates made by polymer matrix and reinforcing fibres.

(Refer Slide Time: 27:39)



Now what are the advantages where let us quickly go through the advantages better productivity low drill breakage, better chip evacuation, decrease in the thrust force, decrease in the drilling temperature, decrease in the drilling induced de-lamination. So you can see all the advantages are associated with the woodpecker drilling cycle. So wherever possible we can go for this type of drilling strategy in making holes in polymer matrix composites.

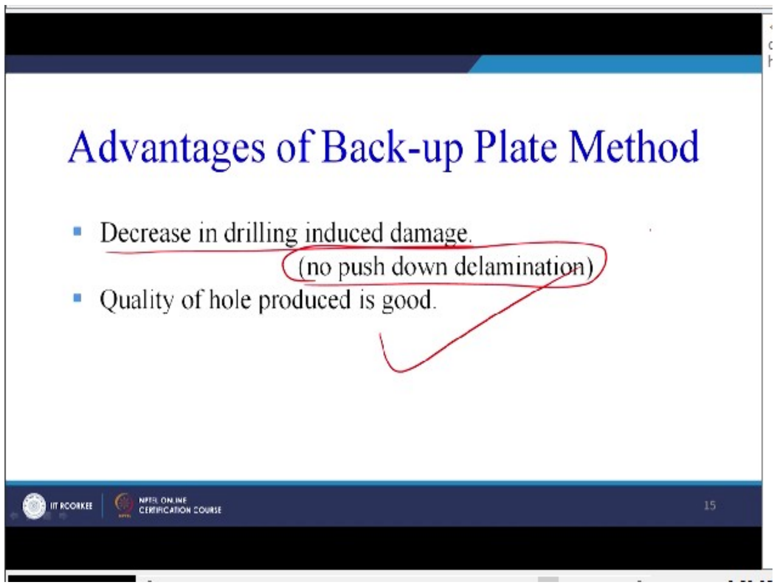
(Refer Slide Time: 28:08)



Now this is the use of the backup plate, this is the drill it is rotating in this direction, it is going down also in this direction and this is the backup plate it is already shown in red colour. So, this backup plate will not allow that de-lamination the bottom layers. Now these are the layers in the laminated composite backing plate, when the drill will go down this backing plate will not allow the lower layers to delaminate.

Otherwise if the backup plate is not there the bottom layers of the fibre will turn to delaminate. So, this type of de-lamination can be easily avoided using this backup plate, now what are the advantages of this.

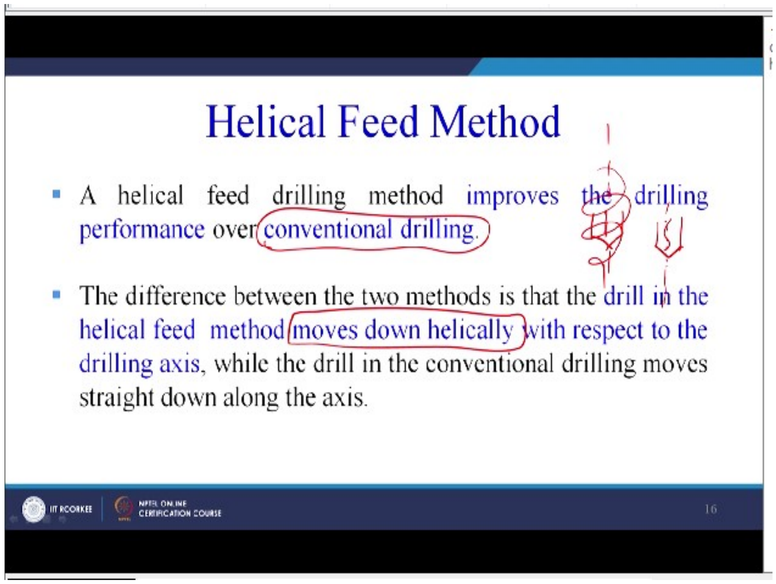
(Refer Slide Time: 28:49)



Advantages of backup plate method are decrease in the drilling induced damage no push down de-lamination as I have explained in the diagram. Quality of the hole produced is very very good. So we have seen, you can put a backup plate below the laminate. So, suppose this is the laminate I want to make hole in I will put a backup plate just below this and clamp this on the work table and try to make a hole through with the drill.

So, the bottom layers of the laminate will not tend to open up. So, the pushdown type of de-lamination can easily be avoided. And a good quality hole can be produced.

(Refer Slide Time: 29:28)



Then there is a helical feed method, a helical feed drilling method improves the drilling performance over the conventional drilling. So, the conventional drilling all of you know, what is conventional drilling?. So, helical feed drilling method is better in performance now what is the helical feed method the difference between the 2 methods is that. The drill in the helical feed method moves down helically.

In conventional drilling method your drill go down in the straight manner whereas treatment in case of helical feed method, the drill will go down in a helical feed. So, it is not straight it will go in a helical feed manner with respect to the drilling axis. So, this is the drilling axis as I have shown in the diagram, so drill go down in a helical manner while the drill in the conventional drilling moves straight down the axis.

So, in case of conventional as I have already highlighted the drill will go down straight along the axis but in case of helical feed it will go down in a helical manner along the axis.

(Refer Slide Time: 30:30)

So, this is an example advantages of helical feed method chip removal is better, flow of the coolant is better most of the time we have to take a decision whether the coolant has to be used or it can be avoided. Thrust force is less, decrease in the drilling induced damage, high quality of hole is produced, temperature produced is less, decrease the matrix burning out problem or matrix burn out problem. So, burn out can be put like this.

So, it can avoid the matrix burnout problem also, so we can see that we can see that we can put up a plate below the composite laminate, we can use a helical feed method, we can use of woodpecker drilling cycle. So, there are different strategies which have been applied by the researchers worldwide to reduce the effect of de-lamination. Whether it is push down lamination or it is a peel up type of de-lamination or it is matrix burning or maybe it is fibre pull out.

So all this problems are associated with polymers which are reinforced with the fibres. So those type of materials can easily be drilled or the holes can be produced in composite materials which are specifically polymer matrix composite materials using any of these strategies. So, the last strategy basically can be that we can go for the vibration assisted drilling also where the drill will be doing its action in the normal manner.

But the will also be vibrating at a ultrasonic frequency, so we can go for those kind of drilling strategies also. We can try to optimize the cutting speed, we can try to optimize the feed rate also many researchers have focused on optimization of the drill point geometry. Today I have named only one geometric which is the twist drill. But there are other where is very specific geometries like 4 phases drill point, parabolic drill point, 8 facet drill point, jaw drill, step drill, bed and spur drill.

There is a long list of drills which have been developed, designed and implemented for making holes in polymer matrix composites. So I think the time is over for today's session otherwise we can discuss this topic in much more details. But the overall objective has been met that we have to be very cautious while designing our products. Why because if the holes are going to be there in the product. The holes maybe associated with certain degree of damage, certain degree of defects which may have a detrimental effect on the performance of our products.

So whenever we are designing a product we must keep in mind the holes that are going to be produce the process that is going to be use for making the holes as well as the damage or the defects that may occur during hole making operations. Because this are going to affect the performance of our product. So with this we can conclude the today’s session, we will start our discussion for the last week and we will see important topics which are left by now and we will try to focus on the topics which are going to be relevant really during the product development cycle.

Thank you.