# A Review on Effects of Drilling Process on the Composite Material

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***Abstract-*** *This paper reviews on effects of drilling of composite material. Several researches have been developed analysing the effects of drilling process on composite materials. From these very few researches have discussed issues related to Delamination factor, drill point angle, feed rate. In addition, the review also discusses challenges undergone during drilling of composite materials. The feature of this review is that it identifies the factor affecting quality in drilling and provides general recommendations for selecting process parameters, drill bit, coated tool materials. The study aims to solve problem by employing nano-coated drills on multi material made up of CFRP and Aluminium alloy.*

***Keywords***- Composites, Delamination factor, Drilling, Machining parameters, Thrust force, CFRP, GFRP.

**NOMENCLATURE**

**GFRP-** Glass Fibre Reinforced Polymer Composite.
**S-GFRP-** Sisal Glass Fibre Reinforced Polymer Composite
**CFRP-** Carbon Fibre Reinforced Polymer Composite
**CFREP-** Carbon Fibre Reinforced Epoxy Polymer Composite
**MWCNT** - Multi walled carbon nano tube
**AEG** -Acoustic Emission Grating
**B4C -** Boron Carbide Composites
**UAD -** Ultrasonic Assisted Drilling

## I. INTRODUCTION

**Drilling** is the important process for making and assembling components, various process like conventional drilling, vibrational assisted drilling have been attempted in order to maintain the integrity of the material and obtain the necessary accuracy in drilling of materials. Drilling is a very common machining operation to install fasteners for assembly of laminates. Composites are used in conjunction with another material to form multi-material stack up provide greater strength to weight ratio. Drilling is the most common operation applied to composites requires only holes for assembly integration. In **Conventional drilling**, hole-enlargement is generally performed after the pilot hole is drilled. Here feed rate, cutting speed are most influential factor on delamination. In **Vibration Assisted Drilling,** drilling is assisted by vibration system in order to improve evacuation of chips under ribbon form while drilling. In **Ultrasonic assisted Drilling**, Drilling device uses vibration to hammer its bit through materials uses piezoelectric actuator as source of power. Vibration assisted drilling and Ultrasonic assisted drilling have lesser thrust and hence lesser delamination compared to conventional drilling, which indicates that both vibration assisted drilling and Ultrasonic assisted drilling are more appropriate for drilling of GFRP.Among all machining operations, drilling using twist drill is the most frequently applied for secondary machining of composite materials owing to the need for structure joining.A **Composite** material (also called a composition material or shortened to composite which is the common name) is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual .**CFRP-**Carbon Fiber Reinforced Polymersare expensive to produce but used wherever high strength to weight ratio is required. **GFRP**-Glass Fibre Reinforced Polymer where Glass-Fibre replaces carbon which is used in spaceship and sea vehicles due to significant advantage over other vehicles[15].A consequence of the widening range of applications of GFRP, the machining of these materials has become a very important subject for research [16].**Glass Epoxy Laminates**– A composite material fibre glass with epoxy resin bind.

## II.EFFECTS OF DRILLING

**Delamination** is a mode of failure for composite materials and steel. In laminated materials, repeated cyclic stresses, impact, and so on can cause layers to separate, forming a mica-like structure of separate layers, with significant loss of mechanical toughness. Delamination is mostly considered as the principal failure model in drilling of Composite materials.

**Peel up delamination** occurs when drill enters the laminate.

**Push out delamination** occurs when drill exits the laminate.

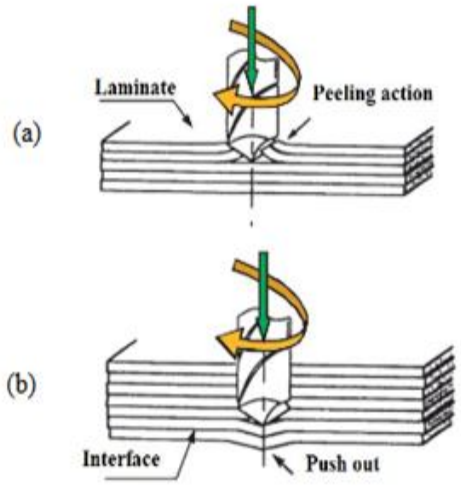


Figure 1. Mechanisms of Delamination: (a) peel up at entrance (b) push out at exit[18].

**Feed rate** units depend on the motion of the tool and work piece; when the work piece rotates (e.g., in turning and boring), the units are almost always distance per spindle revolution (inches per revolution [in/rev or ipr] or milli-meters per revolution [mm/rev]).

**Thrust** is a reaction force described quantitatively by Newton's second and third laws. When a system expels or accelerates mass in one direction, the accelerated mass will cause a force of equal magnitude but opposite direction on that system.

This paper presents a comprehensive analysis on how delamination of carbon fibre composites by drilling can be avoided. The extremely low manufacturing efficiency and high energy consumption of traditional composite processing technologies replace the traditional thermal processing technologies in the aerospace industry.

**TAGUCHI'S METHOD:** The design of experiments was based on the Taguchi method .The Taguchi method is a very robust and powerful method to deal with response influenced by large number of variables .Instead of having to test all possible combinations ,the Taguchi method test pair of combinations. This allows the collection of necessary data to determine which factors most affect the process with minimum amount of experimentation thus saving amount and time.

**NavidZarifKarimi et al.,[1]**studied the factors affecting drilling of carbon /epoxy laminates like thrust force ,feed rate compressive strength, delamination factor which leads to the problem that delamination occur while drilling of composites which reduces compressive strength. Hereby experimentation done by Taguchi principle concludes by saying that while drilling GFRP, thrust force increases before reaching maximum value sudden drop known as delamination occurs. Delamination related to the thrust force, before reaching the critical value (maximum value), delamination can be neglected. In addition to this Feed rate and Drill point angle related to delamination.

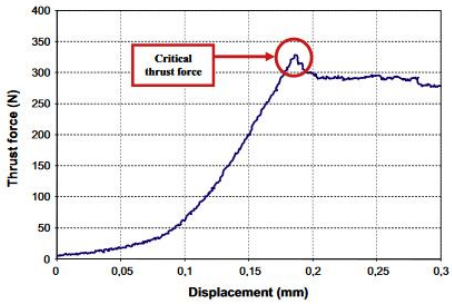


Figure2. Sudden drop in thrust force where delamination occurs.[19].

**P.Rahme et al.,[2]**focussed on the problem that drilling leads to delamination. In this paper drilling of thick composite plate with large diameter drill is studied. The component divided into several parts cutting speed, feed factor, thrust force can be analysed. From the analysis delamination occur at the exit of the hole is major defect, Feed rate is one corresponding to minimum chip thickness reduces delamination at exit.

**M.Ramesh et al.,[3]**analysed that the sisal fibres are incorporated with glass fibre and S-GFRP is prepared. The drilling of the composites is carried out using an auto feed drilling machine and the thrust force for different feed rates are evaluated. The drilling operation with HSS drill leads to maximum thrust force at both the feed rates. The maximum delamination occurs with the HSS drill bit. Hence, it is not recommended to drill S-GFRP composites.

**Nanya LI et al.,[4]**deals with the problem that delamination and thermal damage caused while drilling of CFREP composites. To supress both delamination and thermal damage Multi walled carbon nano tube (MWCNT) introduced to matrix resin composite. The composite was enhanced to microwave curing to provide strength between carbon fibre and carbon nano tubes Concluded by saying that toughness of composite increases by 66% reduce delamination by 16% and so reduce thermal damage.

**XIN Wang et al.,[5]**conceived a new method of testing in drilling CFRP. This study aimed to investigate the wear of certain coated drills. While drilling CFRP, three different drills were used in the experiment uncoated, diamond

coated, Al-TiN coated carbide drill. While drilling CFRPthere is a lack of work material stagnation zone in front of the cutting edge leads to the fracture-based chip formation of CFRP. Series of wear due to the dulling of cutting edge referred to as edge rounding wear or edge recession. Resistance to edge rounding wear over three different drills is investigated. Diamond coating significantly reduce edge rounding wear, However Al-TiN coated drill shows no visible improvement over uncoated drill despite their high hardness it does not protects the drill.

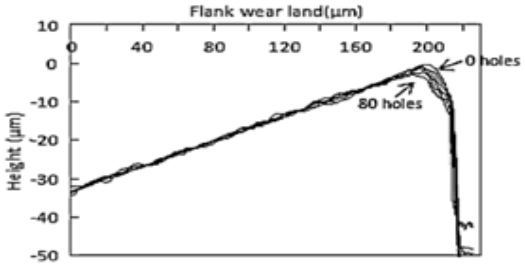


Figure.3.The cutting edge profile of diamond coated tool.

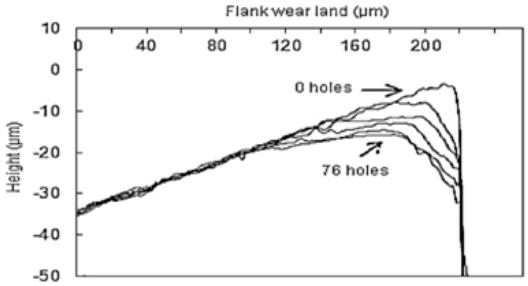


Figure.4.The cutting edge profile of AlTiN coated drill

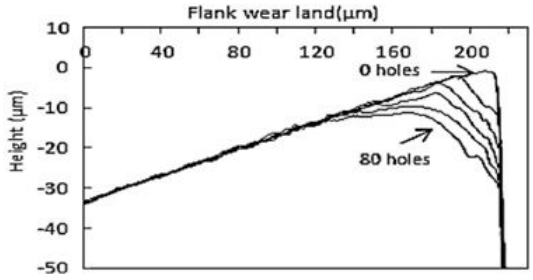


Figure.5.The cutting edge profile of uncoated carbide tool.

Table 1: Wear volume on the substrate and the coatings[13]

| Wear volume per unit length ($\mu m^2$) | Total | Substrate | Coating | Relative wear rate of coatings |
|---|---|---|---|---|
| Uncoated drill | 641 | 641 | 0 | 1 |
| Diamond drill | 71 | 0 | 71 | 0.111 |
| AlTiN drill | 824 | 419 | 405 | 1.820 |

**AhmetTaskesen et al.,[6]**studied that machining parameters were evaluated and optimized with grey relational analysis in drilling B4C reinforced metal matrix composites (MMCs) This composite made by powder metallurgy technique. High Speed Steel, TiAlN coated and uncoated cementide carbide drills were used under dry cutting conditions. Moreover, better surface finish was determined with coated carbide tools, and poor surface finish was obtained with HSS tools. The effect of cutting speed on the surface roughness depended on B4Ccontent and this effect might be ignored when B4C particle content was about 25% or moreboron carbide composite.

**M. Senthil Kumar et al.,[7]**investigated that, while drilling of composites, Experiments were conducted by varying drill parameters in CFRP/Ti stacks and determining the optimum cutting condition using Genetic Algorithm (GA) technique. Tool wear was observed by drilling 100 holes each with 118° and 130° point angle drills, concluded by saying that better chip evacuation achieved in 130° point angle drills compared to 118° point angle drills. Better chip evacuation reduces delamination and tool wear.

Flank wear and chisel edge wear were to be studied for two twist drills will be following.

Table2:Specification of tool with AlTiN coating [14]

| | SGS (SOLID WC-118°) | SGS (SOLID WC-130°) |
|---|---|---|
| Point angle | 118° | 130° |
| Helix angle | 20° | 30° |
| Chisel edge thickness | 1.215 mm | 0.450 mm |

**Krystian k et al.,[8]**studied drilling of CFRP/Ti stacks with two flute and three flute drills and also varying helix angle of 20° and 40°. Drills with higher helix angle suffered from chipping of primary cutting edges when used at higher feed rate. But drill with lower helix angle has stronger cutting edge and is less prone to chipping however resulting in higher cutting forces and temperatures. Any tool or work material improvements that increase tool life will be beneficial. Considerable efforts have been made over the years to develop new and improved materials with better tool life.

**MamidalaRamuluet al.,[9]**made a study on the drilling of composite and titanium stacks and found that fewer holes were produced when high spindle speeds and slow feed were used. It is found that carbide drills outperformed all other tools in terms of tool life, minimal surface damage and heat induced damage on both work piece materials.

**Prabukarthi et al,.[10]** stated that the attaining of lower thrust force at higher feed rates is due to the fact that the modulus of elasticity of the material decreases, which lead to the failure of the material when drilling at high speeds.

Likewise higher thrust force will be obtained at lower feed rates.

**Ho-Cheng and Tsaoet al.,[11]** compared different drilling tools with special geometries. According to theoretical predictions and experimental results, they concluded that the core drill, candle stick drill, saw drill and step drill can be operated at larger feed rates without delamination in comparison to a standard twist drill since the trust force exerted by these special drills are distributed towards the drill periphery rather than to be concentrated at the hole centre reducing the delamination. The thrust force and torque strongly depend on the geometrical features of the primary cutting edge. Point angle and chisel edge length are the main parameters which determine the maximum thrust force on drilling of CFRP composites.

**Vaibhav A. Phadnis et al.,[12]**studied that Ultrasonically Assisted Drilling (UAD) is a novel machining technique suitable for drilling difficult-to-machine materials such as carbon/epoxy composites, where ultrasonic vibrations are superimposed on the tip of the revolving drill bit. Recently, UAD has been shown to possess several advantages in comparison to conventional drilling, including a reduced thrust force and torque, reduced drilling-induced damage and overall improvement in roundness and surface finish of the drilled hole. A constitutive material model suitable to model both volumetric and thermal softening in CFRP laminate under ultrasonic vibrations is proposed.

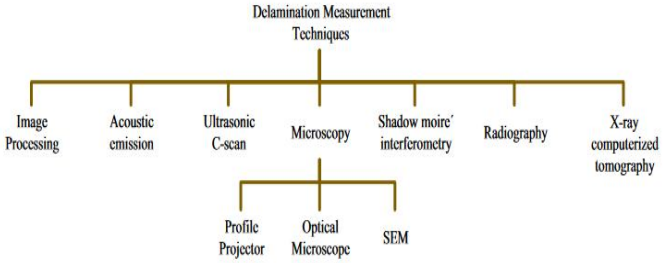


Figure 6.Delamination Measurement Techniques used by various researchers [17]:

**RedouaneZitouneet..al.,[20]** The most common problems encountered in automatic drilling of multi material is that the continuous chip curl up on the body of the tool. This study aims to solve this problem by employing nano-coated drills on multi material made of CFRP and Al alloy. The thrust force generated during drilling of the composite plate with coated drills was 10-15% lesser when compared to that generated during drilling with uncoated drills.

## III. CONCLUSION

The following conclusion can be drawn with regard in several improvements in reducing effects of drilling on composites.

- In conventional machining feed rate, tool material and cutting speed are the most influential and essential factor which causes delamination hence machining at lower feed rate, higher speed, harder tool material and have lesser delamination.
- Drill point angle is also considered for better chip evacuation which reduces drilling damage, delamination, tool wear.
- Vibration assisted drilling and Ultrasonic assisted drilling have lesser thrust hence lesser delamination compared to conventional drilling, which indicate that both drilling methods are more appropriate for drilling of GFRP when compared to CFRP, which shows better result.
- Delamination is neglected after knowing the critical value where delamination occurs.
- Delamination observed in various parts of the composites, it is found that delamination occurs more in exit part more than the entry part of the drilled hole.
- To suppress delamination to further extent, several particles like MWCNT added to composites and further proceed to curing of materials.
- Several tools with different coating over tool material were introduced to reduce delamination to the greater extent.
- Further development in coating over tool materials leads to solve this problem by employing nano-coated drills on multi material made of CFRP and Al alloy which is more effective method when compared to other drills.

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