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Experimental Investigation of drill tool types on delamination error in drilling of CFRP

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Abstract

Carbon Fiber Reinforced Polymer (CFRP) composite is preferred widely in the area of aerospace and automotive industries due to its light weight and high strength. Drilling of FRP composite and its related issues are an important one. The common issue with drilling of CFRP composite is delamination which is most important factor for estimation of delamination error. Selection of appropriate drill tool is one of the methods to control or minimize delamination error. In this work, an experimental investigation is carried out on minimization of delamination effect by selection of appropriate drill tool and process parameters level. Various drill tools are attempted by researchers for controlling delamination error during drilling of CFRP. The important drill types are twist drill, core saw drill and brad drill. The result is noticed that lower value of delamination factor is noticed with higher level of spindle speed (1250 rpm) and lower level of federate (0.10 mm/rev) with core saw drill. Core saw drill and brad spur drill are provided lower value of delamination factor than conventional twist drill. This study is focused on cutting performance with the effect of special drill than conventional one for the effect of delamination error reduction and accuracy. It is noticed that delamination error could be controlled by appropriate drill tool combined with optimum process parameters.

Keywords: Drilling; Delamination; Drill types; CFRP

1. Introduction

CFRP composites are focused in aerospace and automobile industries due to its light weight, corrosion resistance and high modulus. It has unique properties such as anisotropy, lower value of thermal conductivity and high fiber hardness. Hence, drilling of fiber reinforced composites such as Carbon Fiber Reinforced Polymer (CFRP) and Glass Fiber Reinforced Polymer (GFRP) is unusual from the conventional metal drilling process. It is used to make cracks, burrs, uncut fibers and delamination which are leads to functional characteristics such as load carrying capacity, service life of the laminates [1-4]. In joining of composite materials, high quality hole plays an important role which is most requirements of assembly operations. Drilling of composite materials and its related delamination must be studied and minimized. Delamination may be irregular in shape, fiber break outs and cracks in entry and exit of the hole. Delamination factor can be expressed as ratio between diameter maximum obtained to the diameter of required size [5-10].

2. Literature review

Mudhukrishnan et al. [1] performed drilling on Glass Fiber Reinforced Polymer (GFRP) composite using different types of drills. The drill types were twist drill made of High-Speed Steel (HSS), tipped carbide and solid carbide drills used. The result indicated that higher value of drill error is induced with HSS drill due to its less hardness and higher tool

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wear rate than carbide tipped drill and solid carbide drill. Also, a less margin variation of thrust force between carbide tipped drill and solid carbide drills were pointed out. Thrust force is the major reason for occurrence of delamination during process. Qiu et al. [2] studied that the behavior of chisel edge drilling and step drill structure on drilling of composite material. Two categories of drills such as twist drill and step drills were employed. Chisel edge behavior of twist drill and step drill geometry structure were investigated. The result revealed that increased thrust force is noticed with chisel edges when feed rate and cutting speed were increased. Step drill structure was used to achieve better hole quality with larger process parameters and produced good efficiency. Tian et al. [11] carried out drilling process on GFRP composite using candlestick drill. The spindle speed, feed rate and clearance angle of outer edges were considered on damage deformation mechanism. The result pointed out that the combination of machining parameter and tool parameter were significantly affects the material and cutting action. Grilo et al. [12] assessed the effect of three different drills, feed rate and speed on delamination. Spur drill, flute drill and helicoidal drill were used. The result mentioned that spur drill was performed better than other drills. Taso et al. [13] used core saw drill for reduction of delamination error in drilling of fiber reinforced composite. The result revealed that the performance of core-saw drill was better than twist drill due to it allowed larger thrust acting on cutting edge while drilling. Efficient mathematical and digital image processing approaches were used for characterization of drilled image. The significant process parameter was identified as feed rate for controlling delamination error. Xu et al. [14] used twist drill, brad spur drill and dagger drills and its effect on work piece damage and accuracy while drilling of CFRP composite were investigated. The result mentioned that brad spur drill was used to reduce damage due to its lowest thrust force while composite drilling. Hocheng and Tsao [15] used various drill tools such as step, saw, candle stick and core type drills. Thrust forces of all types of drills were investigated. Albuquerque [16] used twist, brad and flute drill types for the analysis of delamination. Artificial neural network was used analyze the results. The result revealed that delamination could be controlled by appropriate drill tool combined with optimum process parameters. Wang and kirwa [17] investigated the hole quality of drilling of CFRP using twist drill, pilot hole and step drills. The effect of input parameters (speed and feed rate) on thrust force during drilling process was investigated. The result revealed that thrust force and hole delamination were influenced by feed rate and step drill. From the literature review, it is understood that drill tool and types are significantly influenced for controlling delamination factor in drilling of CFRP.

3. Material and method

CFRP laminate is prepared by hand lay- up technique. Laminate is prepared using 16 layers of woven roven glass fiber of stacking order zero degree. The fiber volume fraction of prepared laminate is 58.63%, Epoxy (LY566) resin and 5200 hardener is used in the preparation of laminate. Prepared laminate thickness is 5 mm. The prepared CFRP laminate is drilled using vertical CNC milling machine. Figure 1 shows the machine setup. The drilling operation is performed on the laminate by using different speed, feed rate and drill bits (Twist, Brad point & core saw drill). Drilling is performed by three different drills of 8 mm diameter namely Twist, Brad & core saw drill of HSS material. Figure 2 a-c shows the drill tools in this investigation. These values are selected based on previous studies and preliminary experiments.

Table 1 shows the values of process parameters used in this work. Figure 3 shows the machined sample with microscopic images for delamination error measurement.

Figure 1 Machine setup

a) Twist drill	b) Brad point drill	c)Core saw drill

Figure 2 a-c Drill tools

Table 1 Process parameters and their levels

Parameters		Levels	
	Level 1	**Level 2**	**Level 3**
Drill types	Twist drill	Brad point drill	Core saw drill
Spindle speed (rpm)	750	1000	1250
Feed rate (mm/rev)	0.1	0.15	0.2

Drilling induced delamination is measured by using microscope. The delamination factor is determined by the ratio of maximum diameter of the delamination (Dmax) and the diameter of the hole (D).

$$\text{Delamination factor } F_d = D_{max}/D \quad \ldots\ldots\ldots\ldots\ldots(1)$$

Where, Fd indicates the delamination factor, Dmax and D are the maximum damaged zone diameter and hole diameter respectively. Table 2 shows the experimental results.

Table 2 Experimental results

Sl.No	Drill type	Spindle speed in rpm	Feed rate in mm/rev	Delamination factor
1	Twist drill	750	0.1	0.218
2	Twist drill	1000	0.15	0.131
3	Twist drill	1250	0.2	0.127
4	Brad point drill	750	0.15	0.171
5	Brad point drill	1000	0.2	0.118
6	Brad point drill	1250	0.1	0.046
7	Core saw drill	750	0.2	0.146
8	Core saw drill	1000	0.1	0.092
9	Core saw drill	1250	0.15	0.064

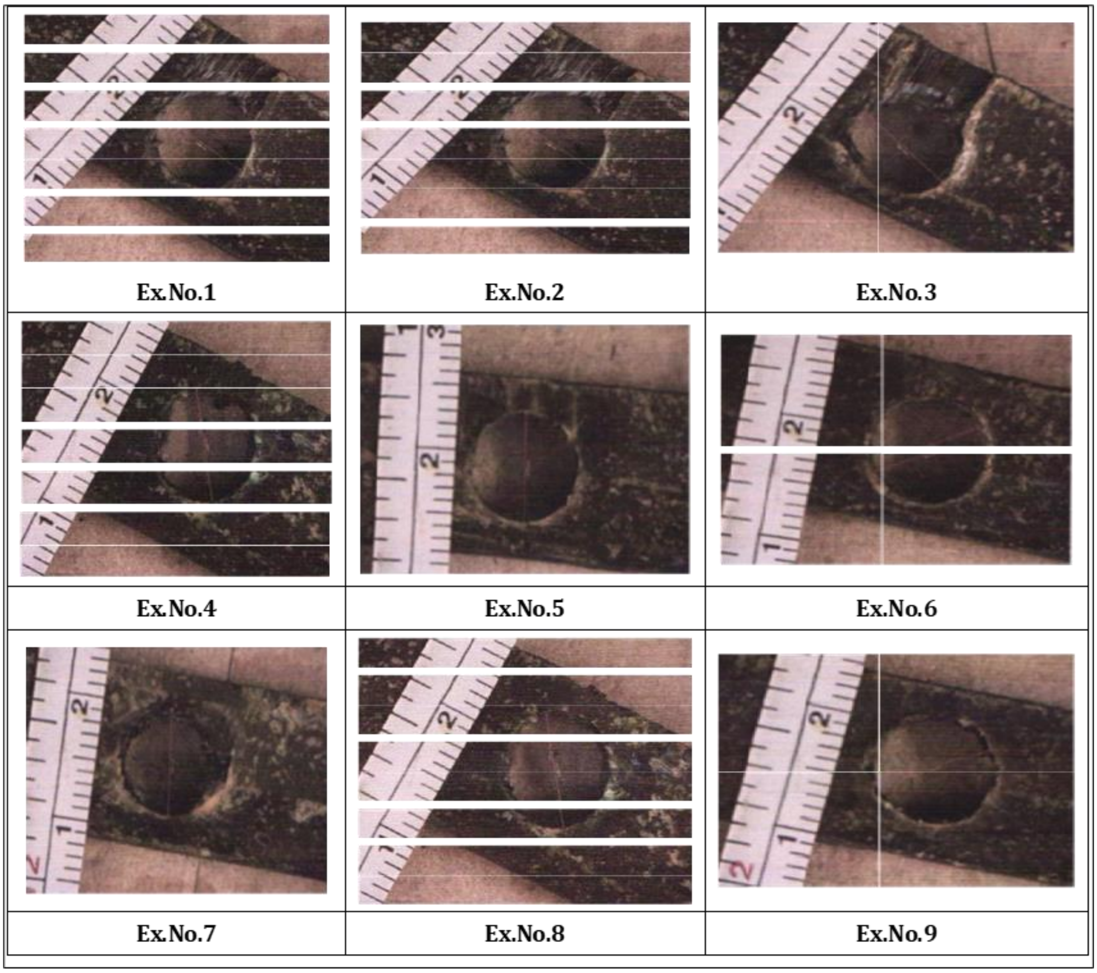
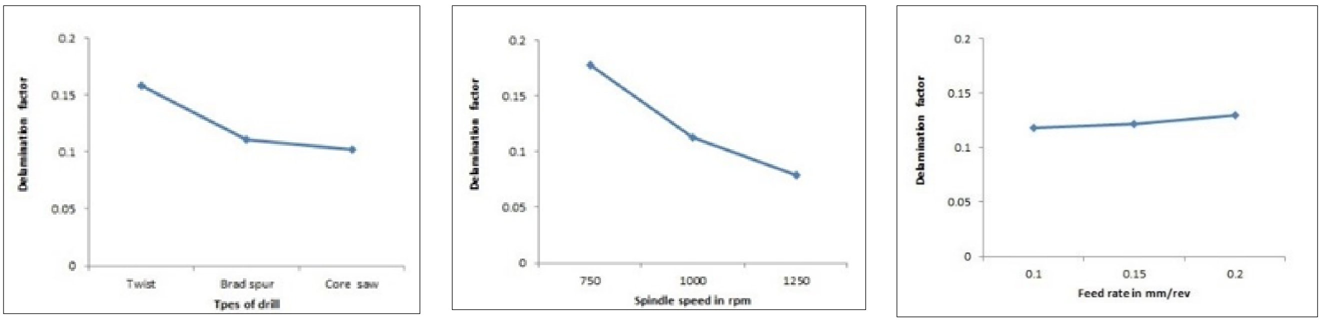


Figure 3 Machined sample with microscopic images for delamination error measurement

4. Results and discussions

In this work, drilling process is carried out on GFRP composite using different drill types and process parameters. Taguchi L9 orthogonal array is used to perform experiments. Delamination factor influences surface integrity and assembly tolerances. Delamination error is a common defect and it must be controlled in drilling of composites. Appropriate drill tool is one of the optimum solutions to control delamination when drilled holes.



a) Effect of drills on delamination factor

b) Effect of spindle speed on delamination factor

c) Effect of feed rate on delamination factor

Figure 4 a-c Main effect plot

Delamination factor is reduced at higher spindle speed, this is leads to high temperature and followed by soft matrix which leads to less delamination. Also, lower feed rate is influencing the delamination error significantly. But, in case of feed rate increases leads to higher delamination error. This is might be high value of thrust force induced [13]. Figure 4 a-c shows the main effect plot. Drill tools play a major role in delamination error. In commercial, twist drill is the first option to perform drilling process in any engineering industries. This type of drill induces more thrust force and leads to bending deformation while performing drilling on the work piece [14]. Also, conventional twist drill has lower value of hardness and higher tool wear rate than specialized drills [15]. Core saw drills are used to reduce damage by reduced cutting edge action, friction between cutting edges and matrix phase softening [16]. Brad spur drill creates the lowest values of thrust forces because of its functionally designed edge geometries. This may be due to its high value of point angle which leads to reduce the friction between tool and work piece. The above reason less value of delamination factor when performing with core saw drill and brad spur drill than conventional twist drill. Lower value of thrust force influences on delamination error which can be achieved by specialized drills like core-saw drill and brad spur drill than conventional twist drill. The specialized drills are undergone low value of delamination error due to its constrained thrust force during drilling process. Optimization process is to be performed for prediction of minimum delamination factor. Also, consider hole quality parameters for investigation [18-28].

5. Conclusion

The following conclusions are derived from the work

- Drilling process is performed on CFRP using different drill tools such as twist drill, brad spur drill and core saw drill. Delamination factor is calculated using microscopic image of drilled hole.
- Delamination error in CFRP composite is a common defect and it is significantly influenced by different types of drill tool and its geometry.
- Delamination is significantly influenced by spindle speed and federate. Less value of delamination factor is noticed with higher level of spindle speed (1250 rpm) and lower level of feed rate (0.10 mm/rev) with core saw drill.
- Core saw drill consist of multiple cutting edges which is significantly influenced the delamination factor. Also, brad spur drill is provided lesser delamination factor than twist drill. This is due to mainly the point angle effect of brad spur drill.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest.

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