Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 5, Issue 06, June -2018

EFFECT OF CUTTING PARAMETERS AND TOOL GEOMETRY IN DRILLING OF GFRP(GLASS FIBRE REINFORCED PLASTICS)

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Abstract —*The Glass fiber reinforced plastics (GFRP) are highly promising materials for the applications in aeronautical and aerospace industries. Machining of these composites, especially drilling is very important operation which is to be carried out. During drilling of GFRP and CFRP delamination is a major concern, which reduces the structural integrity of the material. The present work is focuses on the analysis of delamination behavior of the composites when drilled and methods available to reduce the delamination. Remarkable work has been carried out by different researchers in this area where few have suggested controlling the cutting parameters like cutting speed, feed and depth of cut others have emphasis on thrust force and torque. Some have investigated that tool materials and geometry can make difference. Even the Artificial Neural Network (ANN) is also suggested to predict the delamination. Traditional and non-traditional drilling processes are feasible for making fine holes for composite materials by carefully selected tool, method and operating conditions.in this experiment work three different tools with different geometry like twist drill, step drill and multifaceted drill are used and at the same time feed rate and speed are also taken as variables and optimization of cutting parameters done.*

Keywords*-Glass fibre reinforced plastics; composites; Artificial neural network; Optimization; Delamination*

I. INTRODUCTION

In the recent past, reinforced plastics have largely substituted the conventional materials in most of the fields. Machining operations like milling, drilling, turning and grinding are required to give the final shape to composites. Drilling is a final machining operation for fabrication of composites like GFRP and CFRP. Rejections occurred at this stage is extremely expensive. Machining composite materials differs significantly in many aspects from machining of conventional metals and their alloys. This material has many excellent properties, such as high specific strength, high specific modulus of elasticity, lightweight, and good corrosion resistance. In an aircraft industry 60 % of the total rejections is due to the delamination in drilling of composites. The quality and accuracy of the drilled holes like waviness/roughness of its wall surface, axial straightness and roundness of the hole cross-section can cause high stresses on the rivet, leading to its failure [11, 12]. Stress concentration, delamination and micro cracking associated with machined holes significantly reduce the composites performance.

II. LITERATURE REVIEW

Delamination is considered as the principal failure model in drilling of composite materials. Delamination damaged is happened because of thrust force is identified by many researchers. Damage development and detection, new tool geometries and cutting parameters have been studied for different composites [1, 2, 3]. Several researchers conducted experiments to prove the influence of tool design on machining CFRP. Abrao et al. arrived at the conclusion that the "Brad & Spur" drills obtained the best results concerning mechanical loads and drill hole quality because of the initial cutting at the drill hole wall [4]. Hocheng and Tsao analysed in their works done in 2003, 2005 and 2006 the critical thrust force at the beginning of delamination. They compared five different drill types: a twist drill, a candle stick drill, a saw drill, a core drill and a step drill. For these types of drilling tools an analytical model was developed to predict the critical thrust force. To prove this theoretical model, further experimental investigations were conducted. The results show that the type of drilling tool has a significant influence at the onset of delamination. The best results concerning delamination were achieved with the core drill while the twist drill achieved the poorest results [5, 6, 7]. Velayudham and Krishnamurthy experimented with Normal point geometry tipped carbide drill, Web thinned tipped carbide drill and Tripod geometry solid carbide drill and found that tripod drill performs better compared to other drills and this geometry is found to be producing controlled Thrust and torque [8].

Concerning the drilling of CFRP with higher cutting speeds, Lin and Chen did some investigations in 1996. They analyzed the influence of cutting speed (210 m/min, 530 m/min and 850 m/min) on thrust force, drilling torque and tool wear. The results show that with increasing cutting speeds Vc at constant feed rates f thrust force and tool wear are increasing, while moment stays almost constant [9]. Abrao and Davim focused on the investigation of the effect of the cutting tool geometry and material on the thrust force and delamination produced when drilling a glass fibre reinforced epoxy composite. It can be seen that the thrust force increases with feed rate due to the fact that the shear area is elevated. In contrast, thrust force is not considerably affected by cutting speed within the cutting range tested [10]. It has been established that geometry of the drill bit exerts a significant influence on the hole quality. Several modified drill bits have been designed and developed to manufacture holes in polymer composites and with an observable degree of success [13, 14]. Heisel and Tobias have investigated about the influence of the point angle of a drill tool and increased cutting speeds on machining forces and drill hole quality (delamination, fraying, burr formation)and found that Elevated point angles result in increased feed force while the drilling torque stays almost constant [15]. The tool wear in CFRP machining was quite different from that in conventional metal machining. The primary wear type was a dulling or blunting of the cutting edge, which has been referred to as edge rounding wear or edge recession. A hypothesis has been developed to explain the edge rounding wear in CFRP machining. Due to the fracture-based chip formation of CFRP, there is lack of the work material stagnation zone in front of the cutting edge, which normally prevents the edge wear in metal machining. Series of wear lead to rapid dulling of the cutting edge [16]. . A simple, generic and effective method is proposed to relate drilling to oblique cutting using a direction cosine transformation matrix valid for any drill geometry [17]. Another mathematical model represents the analysis of critical thrust force with special drill bit theoretically [18]. Custom-made double point angle polycrystalline diamond (PCD) drills were used for the experiments which reveals that using higher feeds with lower cutting speed decrease the total power during drilling and would improve tool life without affecting the productivity [19]. Tan Azmi and Muhammad suggested that Feed was the dominant factor for delamination damage and surface roughness followed by spindle speed and tool geometry. Therefore, for achieving high quality holes without compromising the tool life and production rate, the optimum parameters suggested were at middle range spindle speed (7500 rpm), low feed (0.08 mm/rev) and low point angle step drill [20]. Kumar, Dhiraj Singh, K K Zitoune, Redouane Kumar, Dhiraj Singh, K K Zitoune, Redouane have described the experimental investigation in the drilling of glass fiber reinforced polymer (GFRP) composites with three dissimilar tools, having different materials and geometries (i.e. helical flute (HSS) drill, Carbide tipped straight shank (K20) drill, and Solid carbide eight-facet drill). Tool geometry and materials are considered to be major factor, which is responsible for drilling-induced damage. Cutting parameters also influence drilling- induced damage. These damages were measured by two delamination factors. Higher delamination factor, adjusted delamination factor, and surface roughness values were recorded for the helical flute HSS drill. The delamination factor and adjusted delamination factor are lower for solid carbide eight-facet drill com- pared to the other two geometries at 1500 rpm and 0.02 mm/rev. Surface roughness values of solid carbide eight- facet drill are lower than that of the other two drills used. Carbide tipped straight shank (K20) drill can be used for drilling asymmetric laminates of GFRP composites because it has the ability to dissipate heat rapidly [21]. The surface roughness increases with feed rate and decreases with spindle speed irrespective of the tool material. Relatively least surface roughness is noticed for solid carbide drill and maximum for HSS drill. In HSS twist drill, surface roughness increases very significantly for a speed of 2000 to 2500rpm at a feed rate of above 0.15mm/rev. The solid carbide drill is observed to have better drilling performance compared to other tool materials [22]. A comparative analysis has been made to compare the performance of the developed tool with the widely used twist drill. The performance has been compared based on the forces and associated drilling induced damage. It was found that the developed tool geometry gives better results than the traditional twist drill in terms of minimization of forces and damage as well [23].

III. SPECIMEN PREPARATION

Hand lay-up process was used to prepare the woven glass fiber reinforced plastic (WFGFRP) specimens. The specimen is fabricated by keeping the fiber content by volume as 70 %. Fiber percentage was controlled by controlling the weight of the fibers (number of layers). E glass fiber mats (360 GSM) were used to reinforce epoxy resins (LY556). Hardener used was HY951 to mix with epoxy to cure at room temperature. Necessary care was taken to remove the entrapped air during the lay-up process. Rollers were used for this purpose. A gel coat was applied on the mould prior to the lay-up process. The specimens were macroscopically tested to confirm the absence of defects like voids or delamination. The specimen thickness and the fiber percentages selected for this analysis are within the applicable range. The thicknesses of the specimens varied in the range of 4–4.5 mm. Fiber percentages of 45–65 % by weight of woven fabric are used in aircraft's, marine ordinance and electrical applications. Fiber percentages of 40–70 % by weight of woven roving are used in marine and large container applications.

3.1 Material properties

GFRP is used for the experiment work purposes which made from 70 % fibre content by volume and 30 % resin. Material with following properties is tested in controlled environment conditions.

Table.1 Properties of material

Properties	Type-1
Tensile strength(MPa)	530
Tensile Modulus(GPa)	30
Compressive strength(MPa)	490
Compressive modulus(GPa)	29
Density (g/cm^3)	2.3-2.4
Thickness(mm)	4
▸ Woven weaving base E Glass % by volume	75%
▸ Epoxy Resin % by volume	25%
▸ Barcol Hardness(BHN)	62

IV. EXPERIMENTAL SETUP

A drill tool dynamometer (Kistler Dynamometer Type 9272), was used to measure the axial thrust force and torque during the drilling tests. The proportional charge outputs from the dynamometer were fed to a Kistler Amplifier, The charge amplifier converts this charge into standardized voltage signals that can then be evaluated by the downstream signal processing thus producing a scaled voltage output signal proportional to the applied load. The thrust and torque were continuously monitored throughout the test. Kistler laboratory charge amplifiers and signal conditioners (Data Acquisition system) can be controlled by Dyno Ware software supplied by Kistler. It can capture signal up to 1 MHz the dynamometer was mounted on the table on a vertical CNC machining center (Macpower CNC V544). A fixture was used to clamp the laminate at the center of the dynamometer. Figure shows the experimental setup for Drilling of Composites

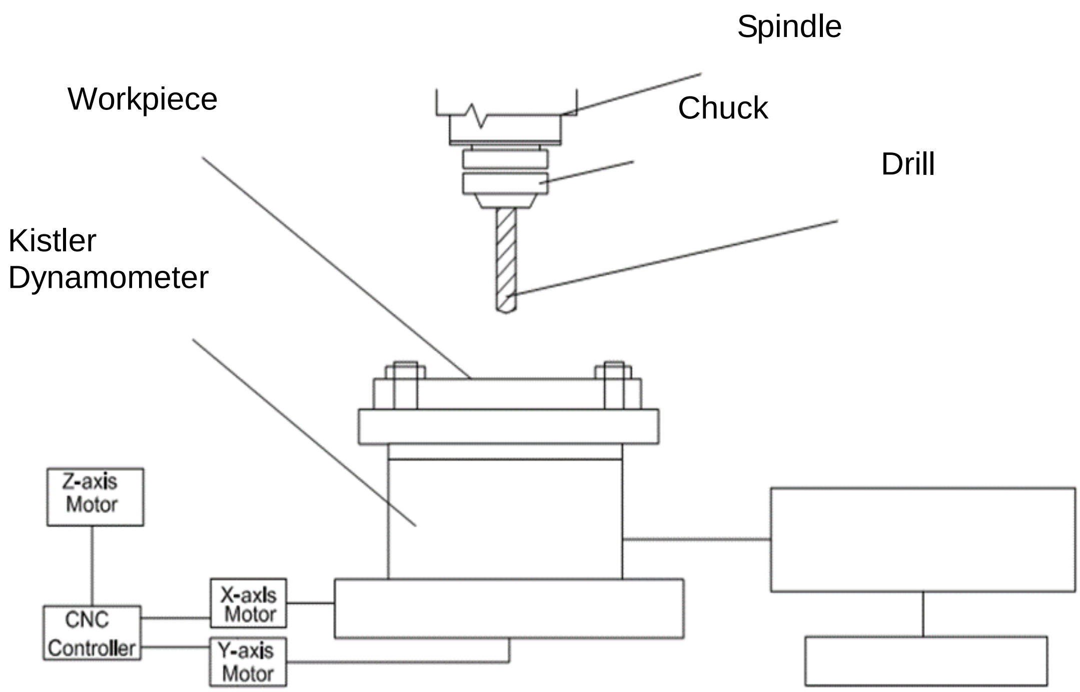


Figure.1: Schematic diagram of Experimental set up

4.1. Cutting Conditions

The main parameters studied are cutting speed, feed rate, and tool geometry on drilling GFRP composite laminates. Machining of FRP material is carried out for the following conditions

• cutting speed: 30, 40, 50 m/min

• Feed rate: 0.05, 0.1, and 0.15 mm/rev

• Tool geometry: standard twist drill, multifaceted (eight facet) drill and step drill

As per full factorial design, 27 experiments were conducted with all possible cutting conditions with multiple measurements for each condition.

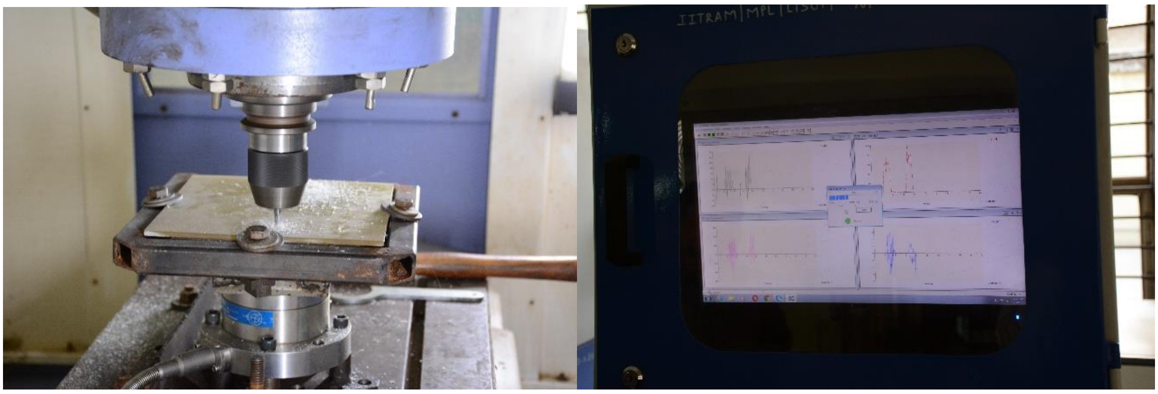
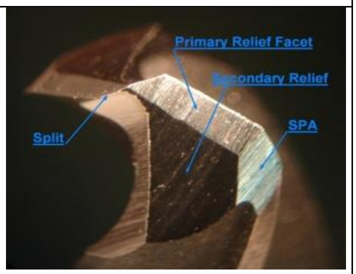


Figure.2 Actual set up and Dynamometer reading

Table.2 Tools and its geometrical parameters

Specification	Twist drill	Step drill	Multifaceted drill
Diameter(mm),Ø	6	6	6
Flute length, mm	2/15	2,3,/15	2/15
Point angle	140°	130°	118°
Lip relief angle	10°	10°	15°
Rake angle	10°	10°	10°
Helix angle	30°	30°	30°
Other specification	Regular	Regular	8 facets
			

V. EXPERIMENTAL DATA COLLECTION

Following data is collected via experimentation work. Experiments were designed in Minitab with Taguchi's experimental technique and three levels of each variables namely feed, speed and point angle of three different tool geometry is taken in to account. Thrust force is measured as an output by online measuring through Kistler Dynamometer and Delamination factor at entry and exit is measured using 3D microscope.

VI. RESULTS AND DISCUSSION

In the present investigation three different variables are taken namely feed rate in mm per minute, speed in rpm and point angle of tools with different geometry i.e. 140° for twist drill, 130° for step drill and 118° for multifaceted drill. One output is Thrust force which was measured online using Kistler Dynamometer Type 9272 and other output is delamination factor measured offline using 3D microscope. Delamination factor (Fd) measured at entry and exit.

Table 3 Observation Table

Sr no.	Feed rate in mm/min	Cutting Speed in rpm	Tool geometry	Code	Code	Code	Average Thrust force in N	Average Delamination factor Fd = Amax/Ao at entry	Average Delamination factor Fd = Amax/Ao at exit
1	100	1500	Twist drill	TD1-1	TD2-1	TD3-1	52.53	1.63	1.70
4	100	2000	Twist drill	TD1-1	TD2-1	TD3-1	60.24	1.87	1.72
7	100	2500	Twist drill	TD1-1	TD2-1	TD3-1	73.61	1.43	1.50
2	200	1500	Twist drill	TD4-2	TD5-2	TD6-2	67.75	2.44	1.68
5	200	2000	Twist drill	TD4-2	TD5-2	TD6-2	84.29	1.94	1.93
8	200	2500	Twist drill	TD4-2	TD5-2	TD6-2	90.29	1.74	1.51
3	300	1500	Twist drill	TD7-3	TD8-3	TD9-3	109.27	2.15	2.02
6	300	2000	Twist drill	TD7-3	TD8-3	TD9-3	106.04	1.80	1.86
9	300	2500	Twist drill	TD7-3	TD8-3	TD9-3	98.19	1.84	1.91
10	100	1500	Step drill	SD1-1	SD2-1	SD3-1	51.68	1.63	1.51
13	100	2000	Step drill	SD1-1	SD2-1	SD3-1	55.40	1.46	1.54
16	100	2500	Step drill	SD1-1	SD2-1	SD3-1	59.35	1.33	1.42
11	200	1500	Step drill	SD4-2	SD5-2	SD6-2	89.44	2.18	1.53
14	200	2000	Step drill	SD4-2	SD5-2	SD6-2	82.36	1.73	1.63
17	200	2500	Step drill	SD4-2	SD5-2	SD6-2	83.74	1.80	1.65
12	300	1500	Step drill	SD7-3	SD8-3	SD9-3	70.66	2.30	1.59
15	300	2000	Step drill	SD7-3	SD8-3	SD9-3	61.54	1.87	1.68
18	300	2500	Step drill	SD7-3	SD8-3	SD9-3	70.48	1.95	1.44
19	100	1500	Multifaceted drill	MFD1-1	MFD2-1	MFD3-1	49.07	1.26	1.30
22	100	2000	Multifaceted drill	MFD1-1	MFD2-1	MFD3-1	59.00	1.40	1.27
25	100	2500	Multifaceted drill	MFD1-1	MFD2-1	MFD3-1	55.52	1.27	1.27
20	200	1500	Multifaceted drill	MFD4-2	MFD5-2	MFD6-2	67.93	1.49	1.44
23	200	2000	Multifaceted drill	MFD4-2	MFD5-2	MFD6-2	64.41	1.50	1.35
26	200	2500	Multifaceted drill	MFD4-2	MFD5-2	MFD6-2	59.14	1.34	1.35
21	300	1500	Multifaceted drill	MFD7-3	MFD8-3	MFD9-3	77.82	1.53	1.47
24	300	2000	Multifaceted drill	MFD7-3	MFD8-3	MFD9-3	72.90	1.47	1.45
27	300	2500	Multifaceted drill	MFD7-3	MFD8-3	MFD9-3	67.00	1.60	1.31

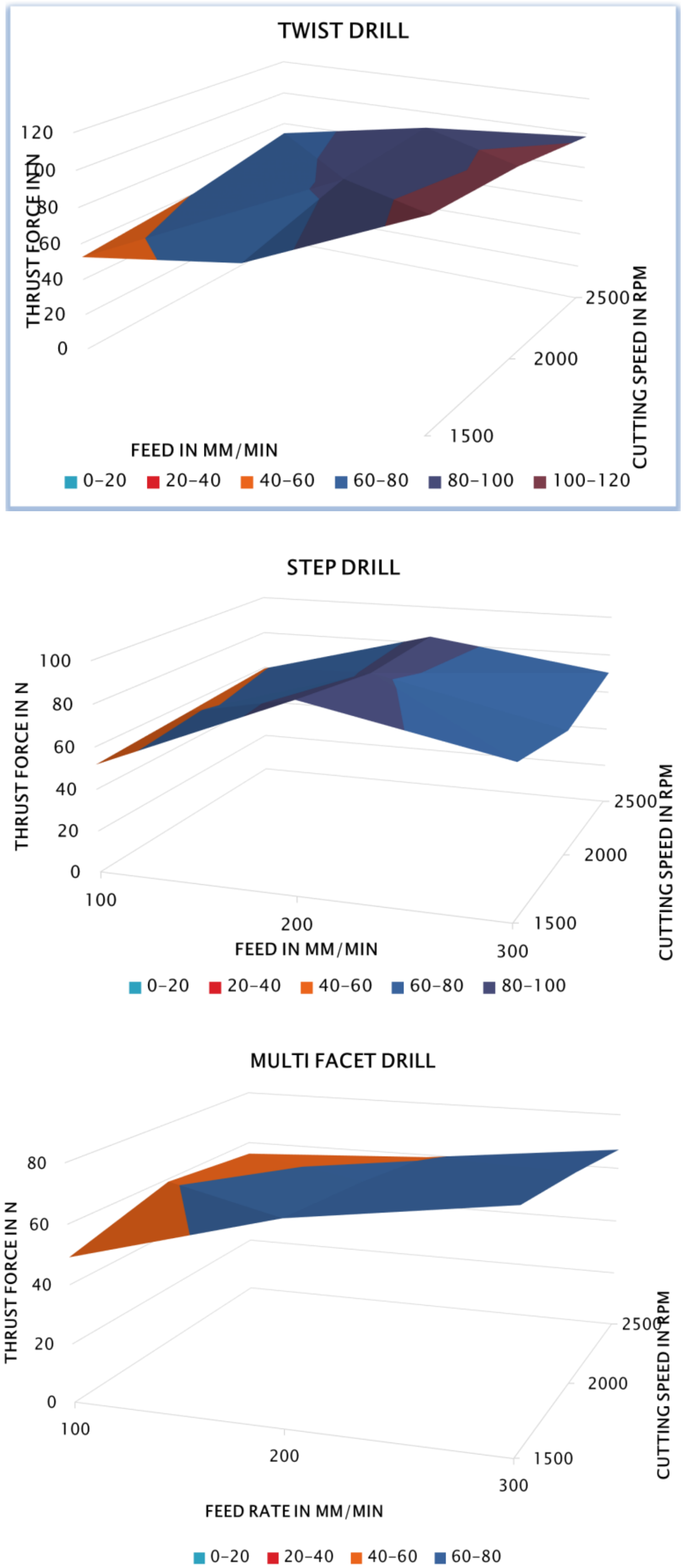


Figure 3 Graphs for twist drill, step drill and multifaceted drill

6.1 Effect of feed

When the feed rate is low the thrust force generated is low and with higher feed rates thrust force is increasing. When we increase the feed rate it will increase the material removal rate but in turn it will consume more energy. If speed is increased with feed rate delamination can be controlled at some extent.

6.2 Effect of speed

As per the observations it is found that the increase in cutting speed reduces the delamination effect. Because higher cutting speeds will reduce the thrust force as the tool will cut more smoothly without ploughing.at smaller velocities it will plough in the work material.it can be seen in the observations.

6.3 Effect of point angle and geometry

It is evident from the study that as the point angle increases the thrust force increases and so the delamination at entry and exit. Carefully selected drill geometry with point angle and small feed rate will generate low thrust force in drilling, which can reduce the risk of induced-delamination drilling.

Figure 4 Drilled Laminate of GFRP

VII. CONCLUSION

From the above experiment and analysis below mentioned conclusion can be derived.

- Analysis was done based on the observation table and different graphs. Charts show that Thrust force F not only rises with elevated feed rates but also increases with elevated cutting speeds.
- Thrust force is the responsible variable for causing the delamination at entry and at exit
- Feed rate is the factor which has a major influence on thrust force followed by point angle
- Minimum thrust force is found at feed rate of 100 mm per minute, speed of 1500 rpm and with multifaceted drill having point angle of 118°.

Combination of Variables can be selected from optimization so that production can be increased and machining time can be reduced.

REFERENCES

[1] Tsao, C., & Chen, W. (1997). Prediction of the location of delamination in the drilling of composite laminates. *Journal of Materials Processing Technology*, *70*(1–3), 185–189. https://doi.org/10.1016/S0924-0136 (97)00059-9

[2] Lin, S.-C., & Shen, J.-M. (1999). Drilling Unidirectional Glass Fiber-Reinforced Composite Materials at High Speed. *Journal of Composite Materials*, *33*(9), 827–851. https://doi.org/10.1177/002199839903300903

[3] Hocheng, H., & Tsao, C. C. (2003). Comprehensive analysis of delamination in drilling of composite materials with various drill bits. *Journal of Materials Processing Technology*, *140*(1–3 SPEC.), 335–339. https://doi.org/10.1016/S0924-0136(03)00749-0

[4] Abrão AM, Campos Rubio JC, Faria PE, Davim JP. The effect of cutting tool geometry on thrust force and delamination when drilling glass fibre reinforced plastic composite. Materials & Design 2008;29:508–513.

[5] Hocheng H, Tsao CC. Comprehensive analysis of delamination in drilling of composite materials with various drill bits. Journal of Materials Processing Technology 2003;140:335–339.

[6] Hocheng H, Tsao CC. The path towards delamination-free drilling of composite materials. Journal of Materials Processing Technology 2005;167:251–264.

[7] Hocheng H, Tsao CC. Effects of special drill bits on drilling- induced delamination of composite materials. International Journal of Machine Tools and Manufacture 2006;46:1403–1416.

[8] Velayudham, A., & Krishnamurthy, R. (2007). Effect of point geometry and their influence on thrust and delamination in drilling of polymeric composites. *Journal of Materials Processing Technology*, *185*(1–3), 204–209. https://doi.org/10.1016/j.jmatprotec.2006.03.146

[9] Lin SC, Chen IK. Drilling carbon fiber-reinforced composite material at high speed. Wear 1996;194:156–162.

[10] Abrão, A. M., Rubio, J. C. C., Faria, P. E., & Davim, J. P. (2008). The effect of cutting tool geometry on thrust force and delamination when drilling glass fibre reinforced plastic composite. Materials and Design, 29(2), 508–513. h

[11] Debnath, K.; Singh, I.; Dvivedi, A. Rotary mode ultrasonic drilling of glass fiber reinforced epoxy laminates. Journal of Composite Materials 2015, 49 (8), 949-963.

[12] Debnath, K.; Singh, I.; Dvivedi, A. Evaluation of surface roughness during rotary mode ultrasonic drilling of glass/epoxy composite laminates. Journal of Production Engineering 2014, 17 (1), 16-20. [8]ttps://doi.org/10.1016/j.matdes.2007.01.016

[13] Latha, B., Senthilkumar, V. S., & Palanikumar, K. (2011). Influence of drill geometry on thrust force in drilling GFRP composites Journal of Reinforced Plastics and Composites. Journal of Reinforced Plastics and Composites. https://doi.org/10.1177/0731684410397681

[14] Feito, N., Díaz-Álvarez, J., Díaz-Álvarez, A., Cantero, J. L., & Miguélez, M. H. (2014). Experimental analysis of the influence of drill point angle and wear on the drilling of woven CFRPs. Materials. https://doi.org/10.3390/ma7064258

[15] Heisel, U., & Pfeifroth, T. (2012). Influence of point angle on drill hole quality and machining forces when drilling CFRP. Procedia CIRP, 1(1), 471–476. https://doi.org/10.1016/j.procir.2012.04.084

[16] Wang, X., Kwon, P. Y., Sturtevant, C., Kim, D., & Lantrip, J. (2013). Tool wear of coated drills in drilling CFRP. Journal of Manufacturing Processes, 15, 127–135. https://doi.org/10.1016/j.jmapro.2012.09.019

[17] Lazar, M.-B., & Xirouchakis, P. (2013). Mechanical load distribution along the main cutting edges in drilling. Journal of Materials Processing Technology, 213, 245–260. https://doi.org/10.1016/j.jmatprotec.2012.09.020

[18] Wei, Y. Y., Xu, J. Y., Cai, X. J., An, Q. L., & Chen, M. (2013). Effect of Drills with Different Drill Bits on Delamination in Drilling Composite Materials. Key Engineering Materials, 589–590, 173–178. https://doi.org/10.4028/www.scientific.net/KEM.589-590.173

[19] Karpat, Y., & Bahtiyar, O. (2015). Comparative analysis of PCD drill designs during drilling of CFRP laminates. Procedia CIRP, 31, 316–321. https://doi.org/10.1016/j.procir.2015.03.094

[20] Tan, C. L., Azmi, A. I., & Muhammad, N. (2015). Delamination and Surface Roughness Analyses in Drilling Hybrid Carbon / Glass Composite. Materials and Manufacturing Processes I, 6914(November). https://doi.org/10.1080/10426914.2015.1103864

[21] Kumar, D., Singh, K. K., Zitoune, R., Kumar, D., Singh, K. K., & Zitoune, R. (2016). Experimental investigation of delamination and surface roughness in the drilling of GFRP composite material with different drills Experimental investigation of delamination and surface roughness in the drilling of GFRP composite material with different dr. Advanced Manufacturing: Polymer & Composites Science ISSN:, 340(July). https://doi.org/10.1080/20550340.2016.1187434

[22] Mudhukrishnan, M., Hariharan, P., Palanikumar, K., & Latha, B. (2016). Tool Materials Influence on Surface Roughness and Oversize in Machining Glass Fiber Reinforced Polypropylene (GFR-PP) Composites. Materials and Manufacturing Processes, 6914(August). https://doi.org/10.1080/10426914.2016.1221098

[23] Debnath, K., Sisodia, M., Kumar, A., & Singh, I. (2016). Damage Free Hole Making in Fiber-Reinforced Composites : An Innovative Tool Design Approach. Materials and Manufacturing Processes, 6914(February). https://doi.org/10.1080/10426914.2016.1140191

