Finite Element Analysis on Influence of Drill Bit Geometry on Hole Accuracy in Drilling HCFRP

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Keywords: Hole Drilling; Hybrid Carbon Fibre Reinforced plastic (HCFRP); Delamination

ABSTRACT – One of the most difficult aspects of machining composite materials is the poor quality of the drilled holes which reduces the composite strength, resulting in component rejection during assembly. This study intends to investigate the influence of drill bit geometry on the hole accuracy in drilling Hybrid Carbon Fibre Reinforced Plastic (HCFRP) plates through simulation of finite element analysis (FEA). Based on the simulation result, drill bit with smaller point angle and higher helix angle within certain ranges has produced the most accurate hole with lesser peel up delaminated area.

1. INTRODUCTION

Drilling is one of the crucial processes in aerospace manufacturing industry due to the tight tolerances required for fasteners like rivets and bolts to attach certain parts for final assembly. Generally, these parts are made from Carbon Fibre Reinforced Plastic (CFRP) but recently more advanced material such as Hybrid Carbon Fibre Reinforced plastic (HCFRP) is utilized, and it promotes higher strength to weight ratio in aerospace application. However, one of the most difficult aspects of machining such polymers is the poor quality of the drilled holes which reduces the composite strength, resulting in component rejection during assembly. Delamination is one of the most severe defects generated by the drilling process as shown in Figure 1. Peeling the laminate on the top layer and pushing action on the thin uncut layer at the bottom of HCFRP leads to the product rejection [1]. This study intends to investigate the influence of drill bit geometry, specifically point angle and helix angle on the drilled hole accuracy in drilling HCFRP plates through simulation of finite element analysis (FEA) which was conducted using ANSYS software.

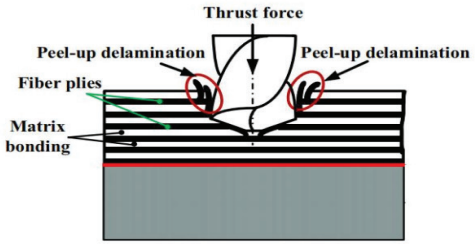

Figure 1 Occurrence of delamination when drilling

2. METHODOLOGY

2.1 Drilling simulation using Ansys software

Figure 2 shows the drilling simulation by using ANSYS software. The HCFRP used as the workpiece in the simulation is CFRP/Al plate with dimension of 30×30×3.6 mm. The CFRP layer with the thickness of 1.20 mm is bonded and sandwiched between two aluminium layers with the thickness of 1.20 mm each. A tungsten carbide twist drill (WC 93% and Co 7%) was employed in the simulation and the diameter of the drill is 6 mm with flute length of 40 mm. The drill bit has a density of 14.35 g/cm^3 and hardness of 1625 HV.

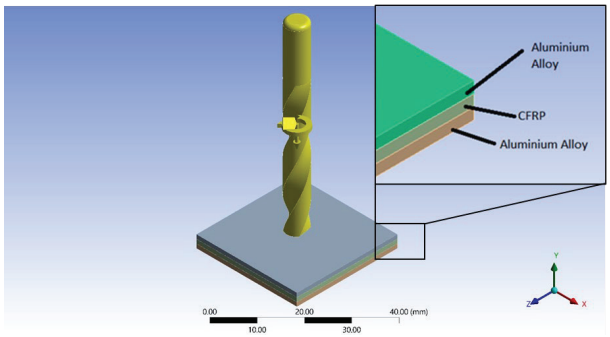

Figure 2 Drilling simulation of CFRP/Al plate

2.1 Drilling parameter and drill bit geometry

In the drilling simulation, the cutting speed and the feed rate are fixed at 22.5 m/min and 0.065 mm/rev, respectively as both parameters are found to be proportional to delamination [2]. The drill bit geometry is focused on the point angle and the helix angle. The low level and the high level for each factor is shown in Table 1. Response Surface Methodology (RSM) with Central Composite Design (CCD) was employed to run the drilling simulation based on the suggested input parameters as to obtain the value of hole accuracy and delaminated area.

Table 1 Two-level factors

Drill Geometry	Low level	High Level
Point angle (˚)	120	135
Helix angle (˚)	20	30

2.3 *Hole Accuracy Measurement*

The top view image of the drilled hole from the ANSYS simulation was captured and analyzed using Image J software to obtain the total area of traced circle (yellow line) as indicated in Figure 3. The hole accuracy is determined by calculating the similarity percentage between the area of the hole generated after simulation and the nominal size of the hole using a drill bit diameter of 6mm (28.2743 mm²), while the delaminated area is determined by calculating the difference area between them.

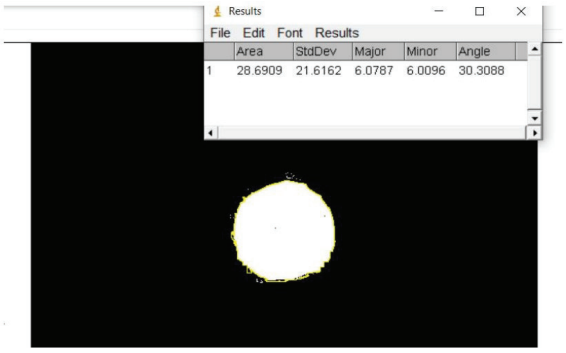

Figure 3 Measurement of the delamination area

3. RESULT AND DISCUSSION

Table 2 provides the result of the peel up delaminated area and the hole accuracy. From the simulation result, the 6th run produced the highest hole accuracy with 99.81% and the lowest delaminated area of 0.0536 mm². Drill bit with point angle of 120° and helix angle of 30° drilled the most accurate hole with lesser delaminated area. The point angle of 120° suitable for drilling HCFRP with minimum amount of delamination and this result coincides with previous study conducted on the twist drill design [3]. The lowest hole accuracy is the 7th run with 98.33% which has point angle of 120° and helix angle of 20° followed by 3rd run which has point angle of 127.5° and helix angle of 20°. It was clearly found that the drill bits with lower helix angle are difficult to produce high quality hole

Table 2 Peel up delaminated area and hole accuracy

Run	Point angle [°]	Helix angle [°]	Drilled Hole Area [mm²]	Hole Accuracy [%]	Delaminated area [mm²]
1	120	25	28.0572	99.23	-0.2171
2	127.5	30	28.4155	100.50	0.1412
3	127.5	20	27.8290	98.43	-0.4453
4	135	30	28.1627	99.61	-0.1116
5	127.5	25	28.0145	99.08	-0.2598
6	120	20	28.2207	99.81	-0.0536
7	120	20	28.8018	98.33	-0.4725
8	135	25	28.3802	100.37	0.1059
9	135	20	28.4487	100.62	0.1744

Figure 3 presents the 3D surface response plot for peel up delaminated area for varied point angle and helix angle of the drill bit. At the point angle of 120° and helix angle of 30° the minimal delaminated area of 0.0536 mm² can be obtained. Further decrease in the helix angle value causes the increment of delaminated area. Whereas, increasing the point angle and remaining same helix angle of 30° degree able to produce minimal amount of delamination within acceptable range.

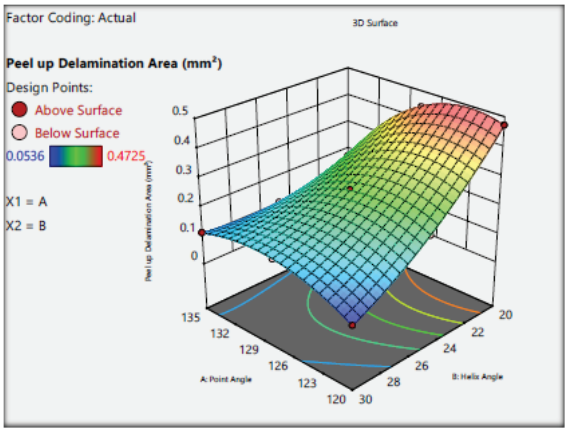

Figure 3 3D Surface response plot for peel up delaminated area.

4. CONCLUSION

Based on the drilling simulation conducted using ANSYS, drill bit with the point angle of 120° and helix angle of 30° produces the most accurate hole with lesser peel up delaminated area. The point angle 120° is suitable for drilling HCFRP with minimum amount of delamination. Whereas, reducing helix angle from 30° to 20° causes significant increase in peel up delaminated area.

ACKNOWLEDGEMENT

This work partially supported by Universiti Teknikal Malaysia Melaka (UTeM) and the Malaysia Ministry of Higher Education for the financial fundings under Grant No. FRGS/1/2021/FKP/F00477.

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