The effect of cutting tool geometry on thrust force in drilling carbon fiber reinforced plastics (CFRP)

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ABSTRACT – Drilling is the most applied machining process in assembling mechanical structures for bolts, rivets, and screws. The anisotropy of composites materials indirectly affects the thrust during the drilling procedure. A series of thrust force experiments are conducted on carbon fiber reinforced plastics (CFRP) using the standard commercial drill. The variation of the thrust force curve shape can be obtained in using different drill bit types. The geometry of the drill bit contributes a significant variation of thrust force. Decreasing point angle value and an increasing total of drilling stages can reduce the thrust force.

1. INTRODUCTION

Carbon Fibre Reinforced Plastics (CFRP) is the rising material for many sectors, especially in aircraft manufacturing and automotive[1]. Its high specific stiffness, high strength to specific weight to ratios, excellent corrosion and fatigue resistance, low thermal expansion coefficient, and very hard to deform, make the CFRP one of the chosen materials for mechanical parts for aviation structures[2]. Nowadays, a modern aircraft such as A380 use more than 80% composites for its mechanical structure.

The drilling process is the mandatory procedure in aircraft manufacturing to assembling each CFRP structure to another. Hence, every drilling process generates feed cutting force or thrust force. The thrust force generated for each drilling varies depending on drill geometry, machining parameters, and materials used itself[3]. This research purposed to investigate the influence of drill geometry and drilling stages to thrust force.

2. METHODOLOGY

The experiment was conducted using a 15kW DMU40 monoBLOCK CNC machining center. The experiment setup is shown in Figure 1. The backing plate was custom made as a fixture to prevent any vibration and influence the cutting force measurement. The cutting force measurement was processed using Kistler Dynamometer type 5223A and displayed by Dynoware software.

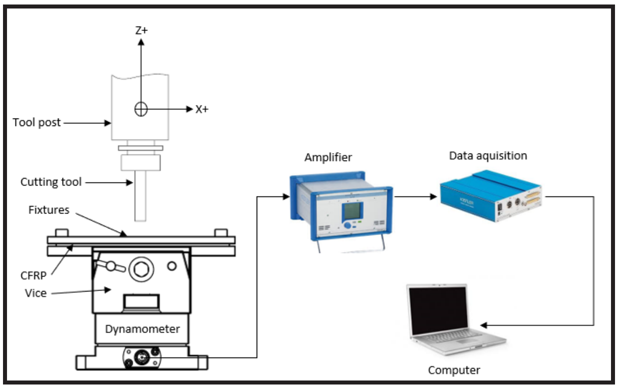

Figure 1 Experimental setup for cutting force

The workpiece of CFRP laminates consists of 26 unidirectional plies, 0.125 mm thickness each. The CFRP plate's total thickness becomes 3.587 mm after including the woven epoxy fabrics at the CFRP plate and paint application's top and bottom. Three different cutting tool geometry types were used in this experiment. All drills' diameter was 6.35 mm and made from tungsten carbide in the composition of 93% WC and 7% Co. Figure 2 and Table 1 show the cutting tool design geometry for this study. Gandtrack Asia Sdn Bhd fabricated the cutting tools. There was no coolant application allowed in this experiment to avoid the coolant liquid obstruct the CFRP laminates. Also, no pre-drill hole was applied in this study, and only new drills were used for each drilling process. Machining parameters were fixed at 2600 rpm and 0.05 mm/rev for spindle speed and feed rate. Drilling depth is 40 mm for all trials applied.

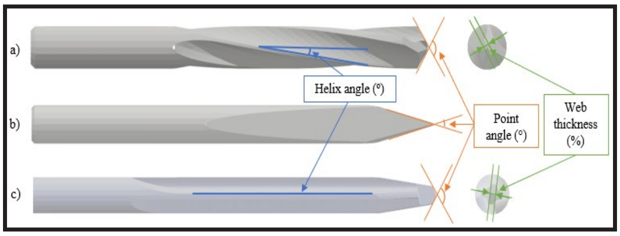

Figure 2 Cutting tool used for the experiment
a) Twist drill b) Dagger drill c) Straight-flute drill reamer

Table 1 Cutting tools geometry design

Features	Twist	Dagger	Drill reamer
Point angle (°)	120	30	90
Helix angle (°)	11	0	0
Web thickness (%)	30	-	30

3. RESULTS AND DISCUSSION

The Dynoware software's measurement was converted to a plotted graph using OriginPro 9.0 software to compare the thrust force generated between drill's geometry variation. Drilling time for all drilling processes was the same hence using the same machining parameters. Equation (1) shows the calculation for the drilling time.

$$T_c = \frac{l_d \cdot i}{n \cdot f^r} \quad (1)$$

T_c is the drilling time, l_d for drilling depth, i for the number of holes, n for spindle speed (rev/min), and f^r for feed rate (mm/rev).

Figure 3 shows the plotted thrust force for the tested drill. The 0s was the drill start to penetrate the workpiece. The twist drill records the highest thrust force generated, and the straight-flute drill reamer records the lowest thrust force. The maximum thrust force was recorded in the penetration stage, in which the first stage of drilling is the main factor contributing to the effect of thrust force generation. The twist drill has 120° of point angle compared to the dagger and straight-flute drill reamer. Increasing the point angle value increases the contacted surface during penetration drilling of the workpiece.

Even the straight-flute drill reamer has 90° of point angle, while the dagger drill 30° of points angle, the maximum thrust force generated using both drills were almost the same. These phenomena occurred due to the total drilling stages to achieve the final hole diameter. The dagger drill has two stages of drilling[4]. Meanwhile, the straight flute drill reamer has three drilling stages to achieve a final hole diameter[5].

The drilling stages can be seen in the curve of the plotted graph of thrust force generated. The twist drill and the dagger drill includes two stages of drilling. The straight-flute drill reamer has three stages but in different lengths of drilling stages. The length of each stage influence the thrust force. The sharp tip of the dagger drill lowered the thrust force because of easily to indent the workpiece. At the second stage of drilling, the dagger drill records the higher thrust force compared to straight-flute drill reamer in conjunction with cutting edges profile. The dagger drill only has two cutting edges, and a straight-flute drill reamer has four cutting edges at the second stage of drilling. This geometry condition allows the straight-flute drill reamer shear the laminates more effective rather than the dagger drill in one complete drill rotation.

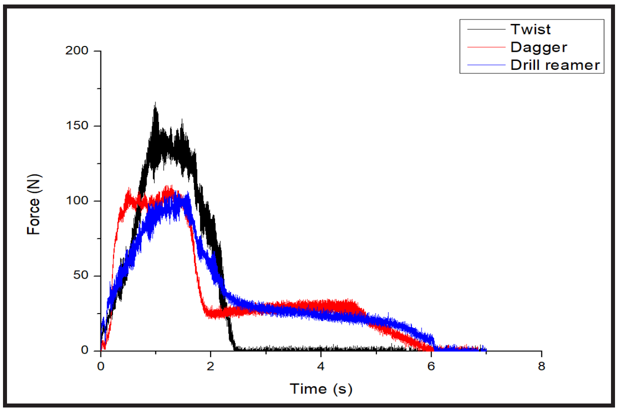

Figure 3 Thrust force comparison between various drills geometry

4. CONCLUSIONS

From the conducted experimental study, the concluding remarks can be derived as:

a. Twist drill records the highest maximum thrust force compared to dagger drill and straight-flute drill reamer.
b. The first stage of drilling contributes to significant thrust force generation.
c. The total drilling stages include achieving the final hole diameter decrease the thrust force.
d. Different drill geometry types contribute to the variation of thrust force generated.

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