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CFRP surface finishing using ceramic brush

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Abstract
This paper presents an investigation about the machinability of CFRP (Carbon Fiber Reinforced Polymers) by employing ceramic brush tool which consists of ceramic fiber bundles. The tips of ceramic fibers work as cutting edges. Continuous fibers provide stable and continuous grinding performances. Experiment has been carried out for different preload, depth of cut, feed rate and cutting speed conditions, where the surface roughness and the cutting force were measured. The surface roughness Ra was found to be between 1~1.5 µm. In the meantime the ceramic brush wear is also observed. Experimental results show that the feasibility of surface milling and finishing of CFRP using ceramic brush tools. Moreover, deburring was achieved very easily.

KEYWORDS : CFRP, Milling, Surface Finishing, Deburring, Ceramic Brush Tool.

1. Introduction

CFRP, a material which shows strength more than iron, weighs less than aluminium and provides stiffness more than titanium, is important material for any manufacturing industry.

Although CFRP products are usually fabricated into net shape, precision machining is often required for parts like shims in order to fill aircraft assembly gaps.

However, grinding is the most leading machining process to produce precision surface. Hu and Zhang carried out classical grinding of both unidirectional and multi directional CFRP by using aluminium oxide wheel operating at 25 m/s and achieved surface roughness almost from 0.2 to 2.4 µm Ra (longitudinal direction) [1][2]. Sein Leung Soo at el investigated diamond abrasive cutters and found surface roughness to be near 3.0 µm Ra [3]. Hiroyuki S. et el used vitrified aluminium oxide grinding wheel as their cutting tool. Surface roughness Rz found to be less than 3.5 µm [4].

This paper presents an investigation about the machinability of CFRP (Carbon Fiber Reinforced Polymers) by employing ceramic brush tool.

Milling, deburring and finishing were challenged. Experiment has been carried out for two types of tool condition, fixed tool and spring tool. For each tool case preload, depth of cut, feed rate and cutting speed was varied, where the surface roughness and the cutting force were measured. In the meantime, the ceramic brush wear is also observed. Moreover, CFRP deburring capability by ceramic brush is checked either.

2. Experiment

The experiment was carried out with vertical milling machine (Hyundai Wia i-cut 380m). The CFRP workpiece was composed of 90° and 0° fiber direction laminates stacked alternatively. Thickness of each lamina was almost 0.3mm and epoxy was used for resin of CFRP (resin content 36.0%). The rotation is set to be clockwise to the direction of feed. For spring tool case, specially designed BT-30 tool holder was used to provide preload.

Figure 1 shows experimental setup. In the setup, cutting force data was measured by dynamometer (Kistler 9257B) and collected with Labview board (Ni USB-6353). Workpiece Multi-directional CFRP (100mmX100mmX20mm) was mounted on workpiece holder installed on dynamometer by bolts. Ceramic Brush (Xebec Co.) (Ø15mmX50mm) was selected for cutting tool. For each cut, images of the cutting tool is been taken by Dino-lite digital microscope (AM 4815ZT) before and after cutting. The difference between this two images helps to observe tool wear.

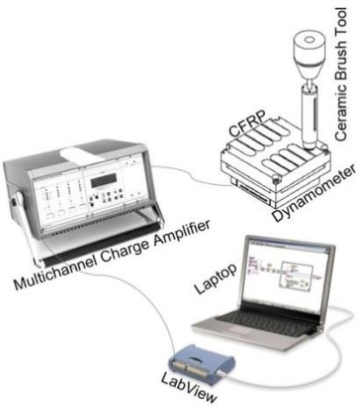

Figure 1. Experimental Set-up for CFRP surface milling using Ceramic Brush.

Table 1 Experimental Conditions.

Preload (N)	0.5, 1.4, 2.8, 9.3, 15, 20
Depth of Cut (mm)	0.30, 0.60, 0.90, 1.20, 1.50
Feed Rate (mm/min)	100, 200, 300, 400, 500
Cutting Speed (m/min)	85, 170, 260, 340, 430

The surface roughness was measured by Surface Tester (Mitutoyo SJ-410). It was measured at perpendicular direction to the fiber orientation.

Ceramic brush tool is consisted of fiber bristle each comprised of 1,000 ceramic filaments. These filaments are only several micro meter (µm) in diameter (10 µm~15 µm). Figure 4 shows a ceramic brush tool with microscopic image of fiber tip.

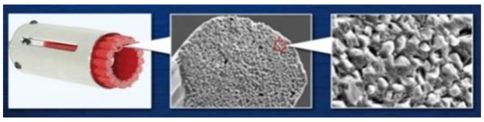

Figure 2. Ceramic brush tool (Xebec Co.) with microscopic image of ceramic fiber tip. [5]

3. Experiment Results

3.1. Preload Effect on Depth of Cut

In case of spring tool, initial preload was generated and changed by adjusting compression of the spring. Although the produced depth of cut is not exactly equal to the spring compression, it has been found that the depth of cut increases almost linearly with the increase of preload.

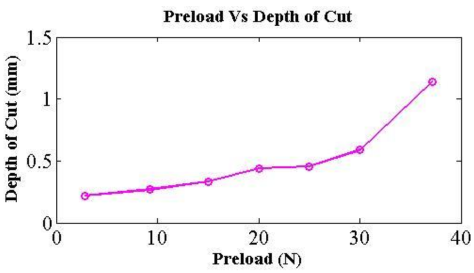

Figure 3. Change of depth of cut according to preload change.

3.2. Fixed Tool & Spring Tool Comparison

It has been found that the surface roughness Ra for spring tool case is between 1.0 µm and 1.5 µm, while for fixed tool case between 1.1 µm and 1.4 µm, which seems almost no big difference. Consequently, both spring tool cutting condition and fixed tool cutting condition produced almost same results.

3.3. Feed Rate Effect

Cutting force increases with the increase of the feed rate for both tool condition. But, it has not much effect on the surface roughness.

3.4. Cutting Speed Effect

In this case, cutting force was decreased with the increase of cutting speed. But, surface roughness Ra remained quite same (between 1 µm ~ 1.7 µm) for all cutting speed conditions.

4. Deburring of CFRP

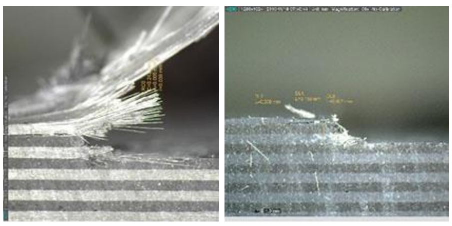

Figure 4. CFRP surface. (Left) Bur generated by tin coated milling tool. (Right) Bur removed by ceramic brush tool.

Aside the experiment of different preload, depth of cut, feed rate and cutting speed, another aspect of CFRP surface finishing was investigated by ceramic brush tool. Deburring of CFRP after CFRP end milling process was tried. At first burr was generated on CFRP surface by milling intentionally with milling Tool (Diameter 14mm, length 73mm, Tin Coated). Deburring operation was done using ceramic brush tool at up-milling side and down-milling side. Both operations are equally effective on deburring.

5. Tool Wear Analysis

Tool wear was found to be propagated from its radial to center at a sloped manner. It was affected by preload and depth of cut condition. As preload and depth of cut got increased, the brush tool was damaged very severely. The damage of tool led to very poor surface condition within a very short period. However, increased feed rate and cutting speed did not affect the tool wear that much.

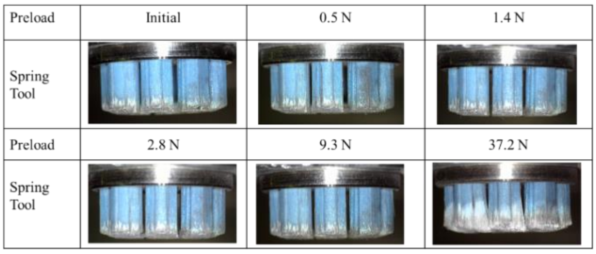

Figure 5. Change of ceramic brush tool wear according to preload change.

6. Conclusion

CFRP surface finishing using ceramic brush tool has been investigated. Fixed tool and spring tool condition found to have no big difference in surface finishing. Preload and depth of cut has significant effect on tool wear. Serious tool wear halts the surface finishing. On the other hand, feed rate and cutting speed have almost no effect on surface roughness and tool wear. Deburring can be successfully done by both up-milling and down-milling side.

Acknowledgement

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