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Study of CFRP grinding method with electrical discharge machining

Yuichi Kitamura[1], Takayuki Kitajima[1], and Tatsuki Ikari[1]

[1]*Mechanical Systems Engineering, National Defense Academy, Japan*

em58010@nda.ac.jp

Abstract
Carbon fiber reinforced plastic (CFRP) is widely used in aerospace and automobile industries because it is lighter and more rigid than metals. However, CFRP is a difficult-to-cut material, and increased production cost is a problem. Hence, various methods have been tested for CFRP machining. This study focuses on electrical discharge machining (EDM) and grinding. A diamond core drill was attached to the EDM electrode while grinding was performed simultaneously. The CFRP used in this study is a unidirectional prepreg (Toray, T700SC) laminated on the inner layer so that the fiber direction shifts by 90°, and the surface is covered by plain woven prepreg (Toray, T300). After machining, the hole diameter was measured with a laser microscope and the surface of the tool electrode was observed. The feasibility of the method was considered from the experimental data obtained.

Key words: CFRP, grinding, electrical discharge machining

1. Introduction

The use of carbon fiber reinforced plastic (CFRP) have been increasing in the aerospace industry owing to its high specific strength compared to metals. However, it is a difficult-to-cut material, and incurs a high production cost. In addition, precision is particularly required in the machining of CFRP used in the aerospace industry. Conventional CFRP machining has problems such as delamination, carbon fiber drawing, and intensive tool wear. Various processing methods are proposed to solve these problems, grinding, electrical discharge machining (EDM), cutting, and drilling. In grinding, tool wear is severe and diamond tools have been developed as countermeasures.

Ito et al. [1] performed electrical discharge machining (EDM) of CFRP and confirmed that EDM of CFRP was possible. In EDM, the numerical values vary greatly depending on the experimental conditions, such as the relationship between voltage and pulse time, and machining time.

Kitajima et al.[2] studied the grinding performance of a grinding wheel against CFRP.

In this study, grinding is performed using a core drill with EDM to examine its feasibility.

2. Experimental method

2.1. Workpiece material

Table 1 shows the specification of CFRP used in this study. The CFRP has a laminated structure that is sandwiched by a plain weaved top and bottom layer and consists of a unidirectional prepreg shifting by 90° in each layer. To improve the conductivity of the material by removing the non-conductive layer of the epoxy, the surface was rubbed with the sandpaper .

2.2. Tool fabrication

The tool electrode used a diamond core drill made of steel having a shaft diameter of 3 mm, with a ⌀ 1.5 mm copper electrode inserted in half. Furthermore, a 1 mm hole was drilled to enable the machining fluid to pass through. Additionally, the diamond core drill and tool electrode were fixed with an adhesive.

2.3. Experimental setup

Figure 1 shows the experimental setup. The vise was fixed on the table of a small hole electric discharge machine (Sodick, K1C). The CFRP sample was fixed using copper plates to improve conductivity. The tool was installed in a 3 mm electrode guide, and the upper electrode part was fixed using a 1.5 mm chuck.

Table 2 shows the experimental conditions. In the experiment, the effects on tool wear and work material were investigated by changing the peak current value (*I*p).

Table 1 CFRP specification

	Surface layer	Inner layer
Carbon Fiber	T300-3000	T700SC-24000
Number of Filament	3K（3000）	24K（24000）
Tensile Strength（MPa）	3530	4900
Tensile Modulus（GPa）	230	230
Elongation（%）	1.5	2.1
Density（kg/m³）	1760	1800

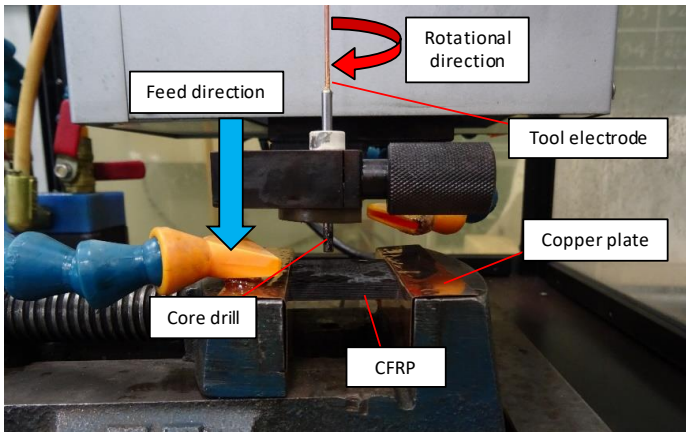

Figure 1. Experimental setup

3. Results and discussions

3.1. Tool wear

Figure 2 shows the effect of peak current value (*I*p) on the tool wear after 1-pass machining. The images were taken the picture by a digital microscope (Saitohkougaku, SKM-Z300C). As the value of *I*p increased, tool wear due to tool melting also increased. Furthermore, the resin of the CFRP adhering to the tool surface was visible. It was considered that the adhesion of the resin to the tool surface was assumed to be the cause of less tool wear because the resin of the CFRP adhering prevented machining. Therefore, when the *I*p value was 13 A or more, there was only a little adhesion of the resin, and the tool melted from the tip. As the *I*p value increased, the amount of melted tool increased. Finally, the abrasive grain of the tool tip melted at 19A.

EDM was possible with an electrode with a core drill. However, future research considering tool wear is needed.

3.2. The diameter and machining time

Figure 3 shows the diameter of the hole measured using a laser microscope after 1-pass machining. As the *I*p value increased, the diameter of the hole expanded. As with normal electrical discharge machining [3], it was considered that the diameter of the hole expanded due to the high *I*p value as the machining amount of the work material increased.

The hole was observed using a digital microscope. On the machining side of the hole, a lot of resin was observed that was similar to the resin adhering to the tool at low *I*p value.

Figure 4 shows the effect of changes in *I*p value on the duration of 1-pass machining. The longest machining time was observed at 2 A. In other words, the machining time was 90 min at 2 A, which is 14 times more compared to that at 19 A. At 2 A, the resin adhered to the surface. In contrast, the tool wear due to melting was small. It is considered that the result of reduced average material removal of machining caused an increase in machining time.

3.3. SEM images of hole side

The SEM images of the 1-pass machining hole side when *I*p = 2 A and 19 A are shown in Figure 5 From the images, at 2 A, the front of the hole did not expand. However, resin melting and un-cut fiber was observed. On the other hand, at 19 A, the front of the hole showed expansion. However, a better machining surface was observed. The low *I*p value caused unexpected resin melting and un-cut fiber.

4. Conclusions

EDM and grinding of CFRP was performed using a tool electrode that was attached to a diamond core drill. From the results obtained in this investigation, the following conclusions were reached:

(1) When the peak current value (*I*p) is small, tool wear was reduced.
(2) The diameter of the hole increased as the *I*p value increased.
(3) The machining time at *I*p = 2 A was about 14 times longer than that at 19 A.
(4) The lower the value of *I*p, worse the surface of the hole side.

References

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[3] Kunieda M 2005 *The Japan Society for Precision Engineering Journal* **71** 58-62

Table 2 Experimental conditions

Tool electrode	Cu(ϕ1.5mm), Steel(ϕ3mm)
Peak current value, *I*p (A)	2, 6, 13, 19
Pulse-on duration, τ_{on} (μs)	30
Pulse-off duration, τ_{off} (μs)	30
Machining fluid	VITOL-KS

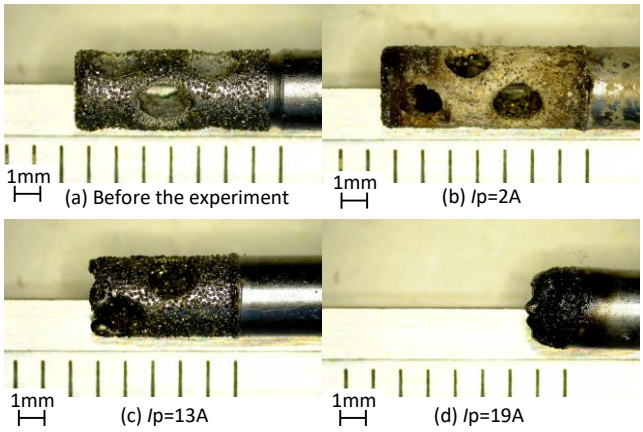


Figure 2. Digital microscope image of the tool electrode

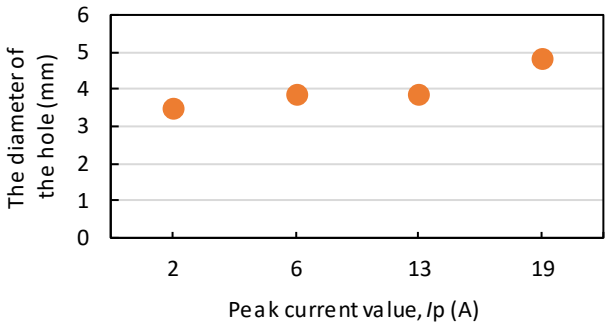


Figure 3. The Diameter of machined hole

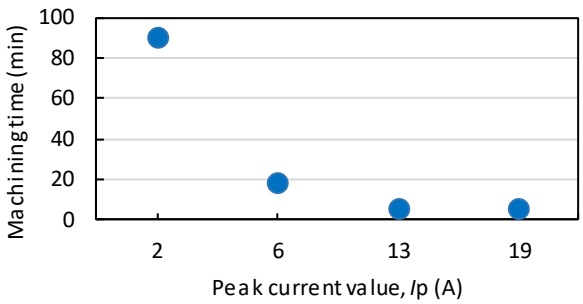
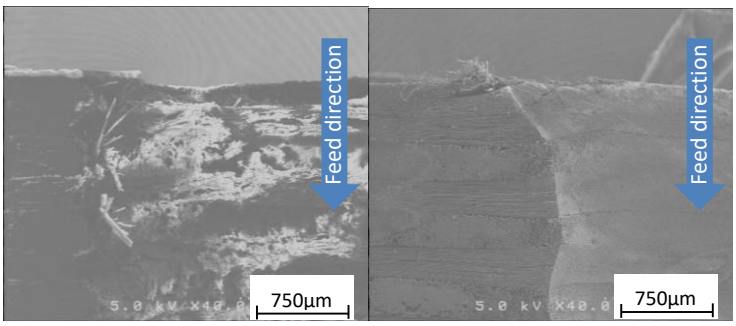


Figure 4. The effect of machining time



(a) *I*p = 2 A (b) *I*p = 19 A

Figure 5. SEM images of machining hole