Impact of cutting parameters on MRR,EWR and hole efficiency in drilling of CFRP by EDM

Suman Kumar

Mechanical Engineering department,

Indira Gandhi Institute of Technology, Sarang, Odisha, India

Dhiren Kumar Behera

Mechanical Engineering Department

Indira Gandhi Institute of Technology, Sarang, Odisha, India

Abstract: ***CFRP composite materials are shortened as carbon fiber reinforced plastic. Owing to its superb properties, i.e. high strength and corrosion resistance, CFRP composite materials consider enormous implementations in many industries. Unsurprisingly, the process of high-strength composite materials for electrical discharge Machining (EDM), particularly as regards CFRP, has few technological knowledge. This study investigates the efficacy, material removal process, and machining disruption of the electrical discharge machine for carbon fiber reinforced plastic composite materials drilling. The EDM technique requires no mechanical energy, thus the hardness, strength or resilience of the work piece does not affect the rate of material removal. The various cutting condition was chosen to conduct the operations, Such as peak current, pulse on time, and hole consistency gap voltage. The resistance to machining was portrayed by the degree of delamination, circularity, hole taper and overcut.***

Keyword: CFRP, Drilling, EDM, Delamination

I. INTRODUCTION

Material selection is one of the most prominent and suspicious sections of the structural or mechanical design process. The material properties to be considered during the evaluation process depend on the performance specifications (mechanical, thermal, etc.) and potential failure modes such as yielding, fracturing, ductile failure, corrosion, overheating thermal failure etc. The modulus and strength are two basic material properties which are often used in the tentative selection of materials for a structural or mechanical design. The modulus is used to quantify elongation for a specific design and the intensity is used to estimate the load's overall carrying capacity. The matrix is used for carbon fiber composite (CFC), carbon fiber reinforced plastic (CFRP), ceramic matrix polymer (CMC), metals and cement or concrete. For CFRP production, different tactics are used, such as fiber winding, autoclave pressing, resin transfer molding for individual and small series manufacturing. CFRP materials demonstrate significantly higher rigidity, considerably greater electrical and thermal conductivity and lower flow rates. Their definitive characteristics mean that CFRP materials are predominantly used in industrial instruments for use in aerospace engineering, automotive industry, high stress and high strength sports equipment, and high inflexibility. Nevertheless, despite such a wide range of applications, carbon fiber-reinforced plastic composite materials are still considered a special group of elements that require considerable attention in machining and are rated as hard to machine materials. Several researchers have mentioned several reasons why CFRP was fundamentally improperly machine. The explanation and the key issues associated with it are discussed as follows :

1. CFRP materials have low thermal conductivity in generic metals and therefore the convective heat during the machining operation is not easily performed outside and therefore the heat tends to be accumulated at the cutting edge (Chen, 1997), contributing in rapid tool wear, which ultimately affects the life of the tool (Lin and Chen, 1996).
2. The low elasticity module of CFRP materials facilitates greater deflection of the workpiece, which pertains to the intricacy of machining such materials (Chen, 1997).
3. There are many issues with standard innovation approaches for CFRP machining, such as drilling, spinning, milling, etc., such as delamination, splintering,

burr presence (Bhatnagar et al., 1995; Chen, 1997; Hocheng and Tsao, 2005; Lin and Chen, 1996).

4. An exceptionally important machining strategy among newly developed non-traditional machining mechanisms is the electrical discharge machining (EDM) (Mc Geough, 1988).
5. In the fabrication of hard-to-machine materials such as ceramics (Wang et al., 2009), composites (Mohana et al., 2004), and tool steel (Che Haron et al., 2001), the advantages of the EDM machining procedure are most conspicuous.
6. The EDM mechanism does not entail mechanical energy, thus, the work piece's stiffness, strength or toughness does not hinder the material removal rate (Mc Geough, 1988).
7. Lau et al. (1990) did the machining of carbon fiber composite plates through electrical discharge. By using EDM as a way of treating composite materials made from carbon fiber they researched the feasibility. The machining was accomplished at diverse currents, length of the pulses and with specific tool materials and polarities. They inferred that, when operating with CFRP, the EDM procedure capability to create unusual formed holes with good surface finish and dimensional precision.
8. Ito et al. (2012) examined the influence of short-circuiting in electrical discharge machining of carbon fiber reinforced plastics.

The objective of this work is to research the effectiveness of machining carbon fiber reinforced plastic material as well as various cutting parameters such as material removal rate, wear rate of the electrode, hole quality such as circularity, taper, overcut by the mechanism of electrical discharge.

II. EXPERIMENTAL ANALYSIS

The observations were carried out using the NC-EDM developed by electronica with model number- EMS-5535 with 350 mm axis in X-direction, 200 mm in Y-direction and 200 mm in Z-direction. Maximum 300 kg job piece can be used.

Fig. 1. NC-EDM Machine

The EDM 30 oil was used as dielectric fluids in action. The electrode was cylindrical in shape, 5 mm in diameter, which is the marginal opening width. Electrode content such as copper is chosen in this examination. The work piece material was delivered by NICKUNJ EXIMP ENTERPRISES LIMITED with carbon fiber reinforced plastic (0/90 grade) dimensions of 50 mm length, 20 mm width and 2 mm thickness.

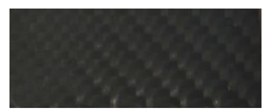

Fig. 2. CFRP material

For this experimental analysis, various EDM cutting criteria were selected for this work, such as pulse-on time, duty cycle, peak current, open circuit voltage, in order to obtain EDM cut condition for CFRP material. Parameters of EDM cutting such as material removal rate, hole size, i.e., circularity, taper, overcut were machined by EDM mechanism. The material removal rate was determined as the weight difference after it was machined before the work piece was machined by the desired cutting time. Weight of the work piece was calibrated using an electronic sensitivity balance of 0.1 mg.

Fig. 3. Weight measurement of work piece and electrode

A coating of non-conductive epoxy resin with 220 grit sandpaper was extracted from the top surface of the work piece to reveal the carbon fiber and let the current pass through the work piece. The work piece was competently held in the machining chucks appliance. The electrode was attached to the Z-axis of the system, and the distance between the piece of work and the electrode was kept at 50 microns and worked by servo mechanism. The initial specification of NC-EDM was to adjust the current, voltage, pulse-on time (Ton) and duty cycle. In order to get a hole, the current and the pulse was changed on time to keep the voltage steady.

Table- I:Different parameters for Machining

Input Parameter	low	medium	High
Ton (μs)	50	75	100
Current(A)	1	5	10
Voltage(V)	30	30	30
Duty Cycle(τ)	60	60	60

Spark erosion occurred during the pulse-on time, which eliminated the material from the work piece and the electrode. The dielectric fluid chilled the electrode and the work piece during pulse-off time and drained the debris away from the gap. In this study, the electrode was anchored to the power generator's positive pole and the reference gap voltage was set at 30v.

Table- II:Parameters used during machining

Sl. No.	Current (A)	Ton (μs)
1	01	50
2	10	100
3	05	100
4	05	50
5	10	50
6	01	75

III. RESULTS AND DISCUSSION

With lower current value I=1A, lower pulse on time value Ton=50μs and constant voltage of 30V, a high quality through the hole was accomplished. It was detected that no burr was found on the tool and the work piece as shown in fig.4. Because of the voltage deviation as shown in Fig.5, burr was formed on both the work piece and the device with current I=10A and time pulse Ton=100μs. With current I=5A, pulse on time Ton=100μs and 30V burr voltage only transpired on the work piece and tool wear was lower, as shown in Fig.6. Burr was established on a piece of work with current I=5A, pulse on time Ton=50μs and voltage of 30V, as shown in fig.7. Again burr structure occurs in a piece of work with current I=10A, pulse on time Ton=50μs and constant voltage of 30V, as shown in fig.8. A blind hole with current I=1A, pulse on time Ton=75μs and voltage of 30V was triggered in the work piece, as shown in Fig.9.

(Fig.4)

(Fig.5)

(Fig.6)

(Fig.7)

(Fig.8)

(Fig.9)

Fig. 10. Final image of work piece after machining

A. Material removal rate (MRR)

The rate of material removal was dictated by estimating the volume ratio of material eliminated from the hole to the machining time needed for drilling the hole.

$$MRR = \frac{\text{volume of material remove}}{\text{Machining time}}$$

$$= 0.0085 \text{ gm/min}$$

B. Electrode wear rate (EWR)

$$EWR = \frac{Eb - Ea \text{ (gm)}}{T \text{ (min)}}$$

$$= 1.104 \text{ gm/min (approx)}$$

Eb and Ea are the weight of the electrode material before and after machining respectively. T(min) is the machining time required to drill the hole.

C. Hole quality

- *Measurement of the hole diameter*

Entry side of the hole :-

Major diameter = 3.109mm

Minor diameter = 3.068mm

Exit side of the hole :-

Major diameter = 3.176mm

- *Delamination*

Delamination factor give the extent of hole edge damage and is defined by,

$$D.F. = \frac{Dmax}{Dactual}$$

Where, D.F. is the delamination Factor.

Dmax is damaged diameter of the circle that encompasses the maximum delamination damage and is concentric with the drilled hole circle and Dactual is the actual hole delamination.

Delamination factor was evaluated at the hole entry as well as the hole exit. The delamination damage was found to be most profound at the hole exit due to the weak bond between the fiber which result in fiber pullout.

$$\text{D.F. in entry side of hole} = \frac{3.109}{3.0}$$

$$= 1.0363\text{mm}$$

$$\text{D.F. in exit side of hole} = \frac{3.176}{3.0}$$

$$= 1.0586\text{mm}$$

- *Circularity*

Circularity is defined as the difference between major diameter and minor diameter of the hole.

Circularity = 3.109 – 3.068

= 0.041mm

- *Taper*

Hole taper was measured as half of the difference between hole diameters at entry and exit.

$$\text{Taper} = \frac{3.109 - 3.176}{2}$$

$$= -0.0335\text{mm}$$

- *Overcut*

Overcut is defined as the difference between hole diameter and tool diameter.

Overcut = Hole diameter – Tool diameter

= 3.109 – 3.0 = 0.109mm

IV. CONCLUSION

In this work, CFRP composite drilling was accomplished using the 3 mm diameter copper electrode which was cylindrical in shape. The experiment was carried out with the help of NC-EDM machine.

A high quality through hole was achieved with lower value of current I=1A, lower value of pulse on time Ton = 50µs and constant voltage of 30V. There was found to be no burr on the tool and the piece of work. With the variation in voltage burr both on the work piece and on the tool was generated. The burr was produced on the work piece only with the medium value of the current, high pulse on time and constant voltage and the tool wear was lower. On the work piece a blind hole was obtained with a lower current, a medium pulse value on time and a constant voltage.

Material extraction of CFRP content in EDM results from decomposition of the epoxy matrix, thermally induced fiber fracturing and fiber vaporization. Delamination occurs primarily on the outlet side of the hole compared to the inlet side because of the weak bond between the fibers.

V. SUGGESTION FOR FUTURE SCOPE

In this study, only peak speed, service cycle, pulse in time and voltage gaps were presumed as parameters for CFRP plate drilling examination. The existence of certain parameters such as acoustic emissions, vibration and temperature therefore needs to be investigated. Hybrid composites, such as nano-particles filled with epoxy carbon fiber composites, have recently found multiple applications in space, defense and military equipment and are another type of drilling material. The research survey revealed that the implementation of these nano-fillers increases the inter-laminar power in CFRP laminates. The tool wear rate can be quantified after the experiment. It also takes a lot of dedication during experiment to reliably calculate the TWR. These work can be expanded to achieve high-quality hole and less device wear for coated electrodes. Aerospace manufacturing companies have now begun to integrate stacked metal / FRP composite systems which provide the device with adequate mechanical stability to extend this configuration for stacked composites. Other possible research programs include modifying the drilling process, enforcing mathematical models and advancing CFRP hybrid composite algorithms for smart machining.

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