Micro Machining of E-Glass-Fibre-Epoxy Composite using Electro Chemical Discharge Machining

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***Abstract* - There is a constantly increasing demand for engineering materials having properties superior to those possessed by customary engineering materials. However, high values of these properties make it more difficult to shape these materials by machining using conventional methods, thereby limiting their widespread applications. Electrochemical machining (ECM) and electro discharge machining(EDM) are the two electrically assisted advanced machining processes which are well established, and are being successfully used in industries for the production of components made of low machinability but electrically conducting materials. The requirement of work piece materials to possess some minimum electrical conductivity is a major limitation of these processes. To overcome this constraint a hybrid process has been conceived, in which the phenomenon of electro chemical spark is employed for material removal from electrically non-conducting materials.**

***Keywords* - ECDM, E-Glass-Fiber, MRR, SEM**

I. INTRODUCTION

Technologically advanced industries like automobile, aeronautics, nuclear, etc. are demanding the advanced materials with high strength, temperature resistance and high strength to weight ratio. To machine the advanced difficult-to-machine materials, newer machining processes have come forward. Newer Machining Processes (NMPs) uses different forms of energies to remove the excess amount of material. Recently, a new trend has been introduced to combine the features of two or more than two machining processes to exploit the potential of each constituent process and diminish their disadvantages. Such machining processes with combined features are called as hybrid machining processes (HMPs). Electro-chemical discharge machining (ECDM) is an innovative hybrid machining process, which combines the features of ECM and EDM and is capable of machining electrically non-conducting materials.

When a low voltage DC supply e.g. 10-25 V is applied between the electrodes (i.e. anode and cathode), insufficient spark was generated. Depending on the nature of the electrolyte and the relative size of the cathode and the anode, gases are liberated at the anode or the cathode. Hydrogen gas bubbles are formed at the tool electrode (cathode) and oxygen bubbles at the counter electrode (anode). When the voltage is increased, the current density increases too and more and more bubbles grow forming a bubble layer around the electrodes. When the voltage is increased above the critical voltage, bubbles coalesce into a gas film around the tool electrode. The electrons emitted due to the breakdown of gas get bombarded on the work piece surface which is placed near the cathode surface and melts it. Various authors have performed ECDM on advance materials like silicon nitride ceramics [5], alumina & borosilicate glass [6], carbon fiber epoxy composites[15] and alumina[19].

II. EXPERIMENTAL SET-UP

An electrochemical discharge machining setup has been designed and fabricated for conducting the experimental investigation (fig.1).

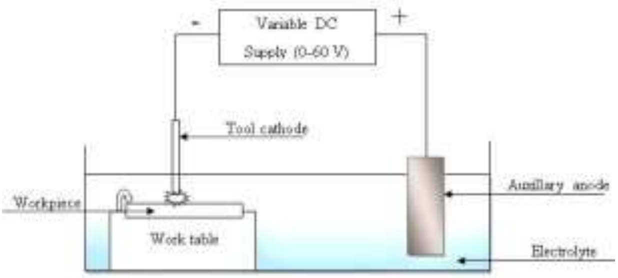

Fig.1. Developed ECDM set-up

Different drilling tests were performed on electrically non-conductive e-glass-fiber-epoxy composite using developed ECDM setup. Table 1 shows the details about the developed machining setup, work-piece and electrolyte used for experimentation.

Table 1 Details for experimentation.

Machine tool used	Developed Machining setup
Electrolyte used	Sodium Hydroxide (NaOH)
Work-piece	Electrically non-conductive e-glass-fiber-epoxy composite (40 × 16 × 2.5 mm)
Cathode (tool)	IS- 3748/ T35Cr5Mo1V30 with diameter of 400 µm

Anode	Copper Plate (Size : 120 x 80 x 1.5 mm)

III. EXPERIMENTAL PLANNING

Table 2 Developed ECDM parameters and their levels

Symbol.	Parameters	Units	Levels			
			1	2	3	4
X_1	DC Supply voltage	Volts	50	60	65	70
X_2	Electrolyte concentration	g/l	65	70	75	80
X_3	Gap between tool and anode	mm	200	190	180	170

Taguchi method based robust design used for experimentation

According to the Taguchi method, L_{16} (4^5) orthogonal array was used for experimental investigation. Table 3 shows the L_{16} (4^5) orthogonal array considered for experimentation.

Table 3. L_{16} (4^5) orthogonal array

Experiment No.	Column		
	1	2	3
1	1	1	1
2	1	2	2
3	1	3	3
4	1	4	4
5	2	1	2
6	2	2	1
7	2	3	4
8	2	4	3
9	3	1	3
10	3	2	4
11	3	3	1
12	3	4	2
13	4	1	4
14	4	2	3
15	4	3	2
16	4	4	1

Dr. Taguchi has combined two components such as desirable and undesirable into one performance measure called as Signal to Noise (S/N) ratio. There are three categories of quality characteristic such as Smaller the better, Normal-the best and Larger-the better. The S/N ratio is used to measure the quality characteristics and it is also used to measure the significant machining parameters through Analysis of Variance (ANOVA) and "F" test value.

Larger-the-better principle

In micro-hole drilling, material removal rate is considered as the quality characteristics based on the summary statistics of the larger-the better principle. The summary statistic, ç (dB) of the larger-the better performance characteristic is expressed as follows:

$$= -10 \log_{10} . \left[1/n \sum_{i=1}^{n} 1/y_i^2 \right]; \quad i = 1,2,\text{--------}n;$$

Where, η is the S/N ratio in dB, n is the number of replication of i^{th} experiments; y is the response value or quality characteristics at i^{th} experiments. The S/N ratios for material removal rate are calculated utilizing the above mathematical relation.

IV. RESULTS & DISCUSSIONS

A series of experiments have been carried out with variation of different cutting parameters and the results are given in form of Graphs. The machining results i.e. material removal rate were obtained at 200 mm gap between tool and anode, 70 g/l electrolyte concentration and for 5 minutes continuous machining with variation of DC supply voltage from 55 volts to 70 volts as shown in fig.2.

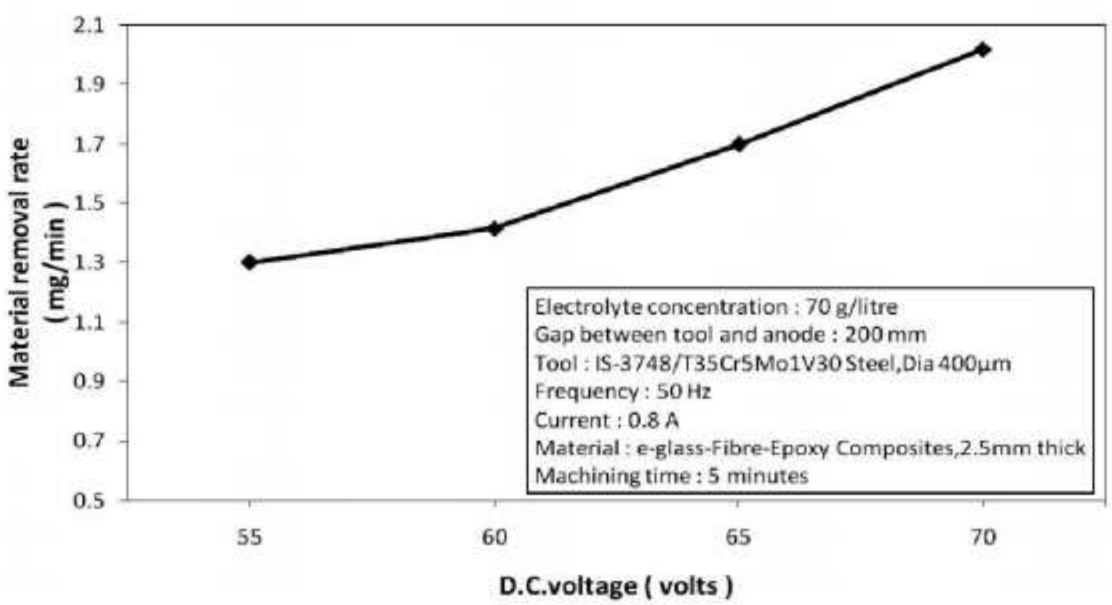

Fig.2 Effect of D.C. Voltage on MRR

The machining results i.e. material removal rate were obtained at 60 volts D.C. supply voltage, 70 g/l electrolyte concentration for 5 minutes continuous machining with variation of gap between tool and anode from 200 mm to 170 mm as shown in fig.3

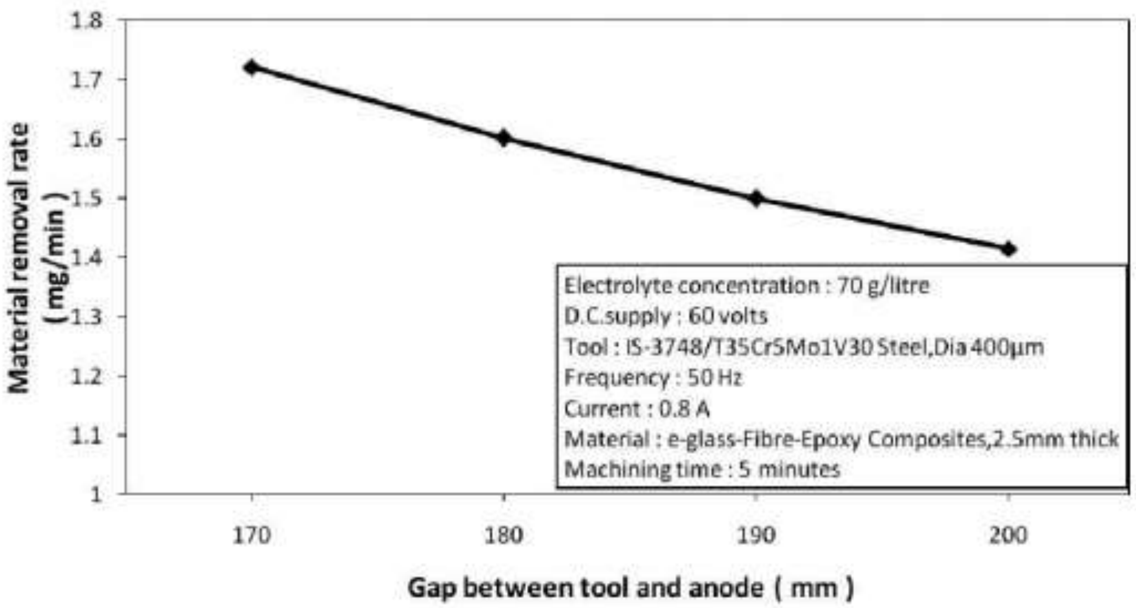

Fig.3 Effect of Gap b/w electrodes on MRR

The machining results i.e. material removal rate were obtained at 200 mm gap between tool and anode, 60 volts D.C. supply voltage and for 5 minutes continuous machining with variation of electrolyte concentration from 65 g/l to 80 g/l, as shown in fig.4.

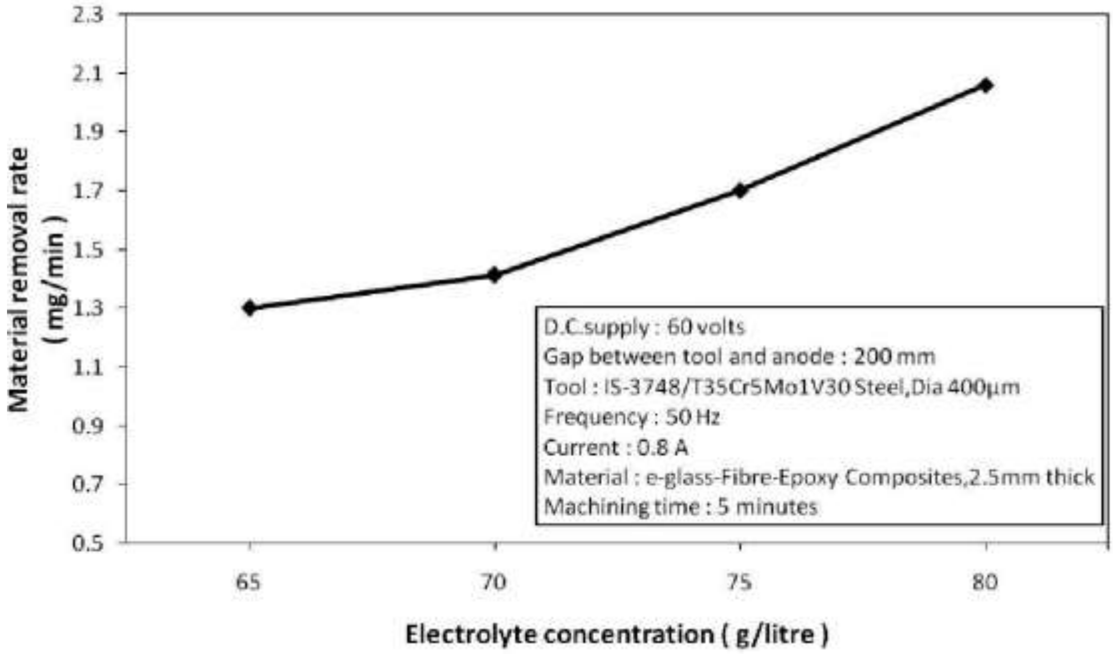

Fig.4 Effect of electrolyte concentration on MRR

Figure 5 shows the S/N response graph for material removal rate, from S/N ratio curve it is concluded that optimal parametric combinations for maximum MRR (mg/min) is A4B4C3.

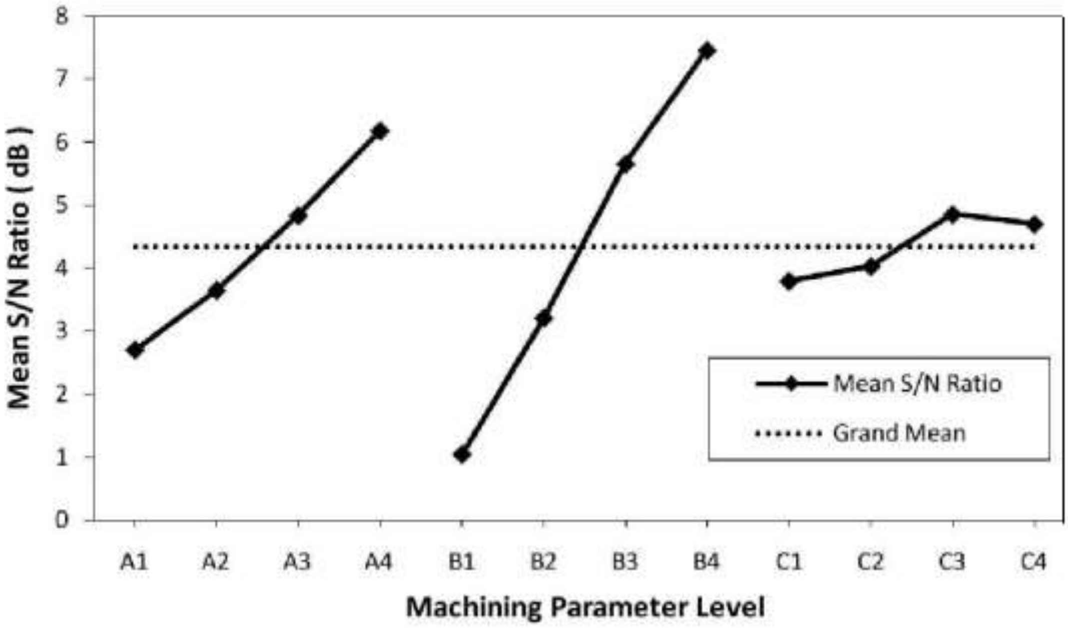

Fig. 5 S/N Ratio by their factor level for MRR, mg/min

ANOVA for Material Removal Rate (MRR)

Table 5.15 shows the ANOVA and "F-test" values with percentage of contribution i.e. effectiveness of the individual machining parameter on material removal rate. This ANOVA table is prepared by utilizing the experimentally obtained results during micro-drilling of electrically non-conductive e-glass-fiber-epoxy composite using developed electro chemical discharge machining (ECDM) set up.

Table 4 : ANOVA for MRR using developed ECDM set up

Sr. No	Control Factor	Sum of Squares	Degree of freedom	Variance	F	%age Contribution
1	DC Supply Voltage	4.852	3	1.6171	155.81	20.57
2	Electrolyte concentration	18.0126	3	6.00421	578.36	76.38
3	Gap between tool and electrode	0.1562	3	0.05208	5.02	0.68
4	Error	0.5606	54	0.01038		2.37
5	Total	23.5822	63			100

SEM Graphs

Figure 6 shows the SEM (Scanning Electro-Microscope) picture of a blind hole generated during drilling of e-glass-fiber-epoxy composite on designed and developed electro chemical discharge machining (ECDM) setup. The blind hole is generated with parametric setting values at 55 volts D.C supply voltage , 65 g/l electrolyte concentration and 200 mm gap between anode and cathode (i.e. parametric combination is A B C) for 1 1 1 continuous 5 minutes of machining.

Fig. 6 Scanning Electro-Microscope of a blind hole

V. CONCLUSIONS

- The material removal rate increases with increase in voltage, increases with decrease in gap between the electrodes & increases with increase in electrolyte concentration.
- The electrolyte concentration has a most significant effect on material removal rate with 76.38 % contribution. The contribution of D.C. supply voltage on material removal rate is 20.57 %.
- For maximum material removal rate, the optimal parametric combination is A B C i.e. material removal 4 4 3 rate is maximum at the parametric combination of 70 volts DC supply voltage, 80 g/l electrolytic concentration and 180 mm gap between anode and cathode.
- From the SEM graph, it is concluded that the surface generated during micro drilling of e-glass fiber epoxy composite is very poor. The reinforce epoxy fibers are not completely cut during machining rather burnt and make integrated many of them together, as a result rough fabric surface is appeared in the form of debris

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