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Optimization Design of EDM Machining Parameter for Carbon Fibre Nano Composite

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Abstract
In this research work, the grey relational analysis (GRA) is used as an optimization tool to find out the suitable process Parameters for the machining of carbon nanotube-reinforced carbon fiber Nano composite. In discrete space degree of relation of different data sets analysed by GRA. In this experimental work, four process parameters are selected, namely peak current (Ip), pulse on time (Ton), duty cycle (η) and gap voltage (Vg), and the significant effect on material removal rate (MRR) and tool wear rate (TWR) has been calculated. Both are considered as the main input variables for the selection of suitable process parameters. Predicted process parameters by GRA show significant increment of 0.000003 in MRR and significant reduction of 0.001904 in TWR.

Keywords:
Carbon nanotube (CNT) · Die-sinking electro discharge machine (EDM) · Grey relational analysis (GRA) ·

1 Introduction

Metal removal process of die-sinking EDM is a thermal erosion process [1, 2]. In this process, material is removed using a series of recurring electrical discharges between two electrodes: one is the tool and the other is the work piece in the presence of selected dielectric [3, 4]. The amount of generated heat within the discharge channel is predicted to be as high as 1017 W/m2 and thus could raise electrode temperatures locally up to 20,000 K even for short pulse

1.1 Working Principle of EDM

In electrical discharge machining process material is take away by striking of continuous spark discharges between the tool and job. In EDM process tool is made up of cathode and work material as anode. In this process work piece and tool are separated by a small gap of about 0.01 to 0.50 mm and both are completely immersed in dielectric fluid. In EDM metal can be removed partially by melting and partially by vaporization. When a suitable gap is maintained between work piece and tool (anode and cathode, respectively), an electrostatic field is generated that results in the emission of the electrons which discharge the dielectric fluid and break them into electrons with higher velocity and positive ions [9–11].Analysis of machinability of different grades of Inconel over die-sinking EDM was carried out using four-level, five factor L16 orthogonal array Taguchi method used for the optimization of parameters [12–14]. The influence of peak current, gap voltage, pulse on time and pulse of time on MRR and TWR is investigated with the help of L18 orthogonal array Taguchi method. In this research, peak current and gap voltage have their significant effect on MRR and TWR [15–17]. Multi-response GRA technique is applied to optimize the selected process parameters, and the main effect plot shows the impact of these parameters on material removal rate and surface roughness, and it is found that both of these are directly proportional to the peak current The latest achievement in the field of EDM have forwarded due to arising function of EDM route and the difficulty being faced by the current industries, from the progress of recent metals that are hard to process such as tool steels, mnemonics, carbides, Hastelloy, wasp alloy, composites, ceramics and different grades of steel mostly used in mould and die developing factory, area of aerospace, area of aeronautics and area of nuclear industries. EDM also shows its presence in areas such as sports, optical, medical, dental, making of jewellery, surgical instruments and research in the field of automotive Carbon fiber-reinforced composite (CFRP) performance is dependent on the carbon fibre matrix interface properties. To improve the properties of carbon fiber/epoxy interface composites, number of researcher introduce CNT and grapheme GRA, invented by Deng in 1982, works on the some specific concept of information. GRA includes two extremes

1. On the one hand, no solution can be found/defined for any system with indication of no information.
2. On the other extreme, a system with perfect information has a unique well-defined solution.

1.2 Work piece and tool material

CNT-reinforced 10-layered carbon fibre nanocomposite is used as work material. Due to the resence of MWCNT,electric conductivity of workpiece is enhanced due to electric conductive nature of CNT [25, 26]. Table 4 showsthe general description of workpiece. LY556 epoxy mixedwith calculated mount of multi-walled carbon nanotube(MWCNT) is sonicated with the help of sonicator (horntype) for 0.4 h, and after that, MWCNT is totally dissolvedin the epoxy. After that, HY5200 hardener was mixed with this sonicated mixture and processed by ball mill for 0.7 h at 200 rpm. After that, the mixture is degassed using a vacuum oven at 65 °C for 1.5 h. Hand layup process was used for spreading the mixture over carbon fibre, and after that, that sample is cured at 160 °C for 4 h. This developed material is presently utilized by aerospace industry widely. This is also utilized by robotic

Fig. 1 CNT-reinforced 10-layered carbon fiber Nano composite

Fig. 2 Copper–cadmium tool

Industries for making lightweight robots, and CNT-based composite also knocks door of our daily life in the form of numbers of application. Figure 2 shows the work piece used in the experiments. Copper–cadmium is used as tool electrode material in experimental work. Figure 3 shows the tool material. General description of tool electrode is given in Table 5.

3 Experimental details

3.1 Experimental setup

In this experiment, Sparkonix ZNC electro discharge machine is used. This is a die-sinking electric discharge machine. Main feature of this machine is that its Z axis is fully numerically controlled with the movement of 250 mm. x and y direction movements are 350 mm and 250 mm, respectively. This machine is equipped with two-nozzle flashing system. Specification of ZNC machine used in the

Table 1 EDM and its specification

Sr.no	Parameters	Specifications
1	x direction movement	350 mm
2	y direction Movement	250 mm
3	z direction Movement	250 mm
4	Maximum electrode weight-bearing capacity	50 kg
5	Maximum job weight-bearing capacity	500 kg
6	Shut height	135 mm
7	Pump motor capacity	0.5 HP
8	Dielectric tank capacity	240
9	Work tank size	900 × 550 × 375 mm
10	Work table size	600 × 400

Experiment is given in Table 1. Shows the electric discharge machine which is used in this research as an experimental kit. Dielectric used in experiment is EDM oil supply by Gandhar industry. It is the most commonly used EDM oil and most suitable for machining on EDM.

3.2 Experimental plan

In the present research work, L9 standard orthogonal array is used which is a suitable array for three levels of parameter Table 2 shows the selected parameter and their level and their show indicates standard L9 array used in experiment; L9 provides sufficient and necessary information with respect to experimental nature and finds out the effect of changing variables and the appropriate way for the improvement in quality during the experimental design process.

Table 2 Process parameters and level

Machining parameter	Level 1	Level 2	Level 3
Peak current (Ip) (Å)	6	8	10
Gap voltage (Vg) (V)	60	70	80
Pulse on time (Ton) (µs)	24	26	28
Duty cycle (η)	0.6	0.7	0.9

4 Methodology steps

1. Maximum and minimum values of MRR and TWR are calculated.
2. Form the normalized table of MRR and TWR.
3. Calculate the deviation sequence for each response.

4. Make a table showing the grey relational coefficient of each performance characteristic.

5. Calculate the overall relational grade for the given responses.

6. Calculate the mean of overall grey relational grade for process parameters, and rank is assigned to each parameter.

7. Calculate the difference between max and min of grey relational grade (mean value), which signifies the importance

Table 3 L9 Array with parameter

Experiment no.	Ip	Vg	Ton	η
1	6	60	24	0.6
2	6	70	26	0.7
3	6	80	28	0.8
4	8	60	24	0.6
5	8	70	26	0.7
6	8	80	28	0.8
7	10	60	24	0.6
8	10	70	26	0.7
9	10	80	28	0.8

4 Method of measurements According to the L9 array, nine experiments are carried out. One experiment is the average of three experiments on the same data. The standard L9 array is used in the experiment with process parameters given in Table 2**.**

Table 4 Material Removal Rate

Exp. no.	Weight before machining (g)	Weight after machining (g)	Material removed (g)	Time of experiment(min)	MRR (g/min)
1	0.9904	0.989402	0.000998	25	0.0 0003992
2	0.9548	0.954334	0.000466	25	0.00001864
3	0.9878	0.987358	0.000442	25	**0.00001768**
4	0.9453	0.944833	0.000467	25	0.00001868
5	0.8939	0.892909	0.000991	25	0.00003964
6	0.9867	0.985698	0.001002	25	**0.00004008**
7	0.8993	0.898841	0.000459	25	0.00001836
8	0.9932	0.992731	0.000469	25	0.00001876
9	0.9989	0.998468	0.000432	25	0.00001772

Bold values indicate minimum and maximum range of MRR

Table 5 Tool wear rate (TWR)

Exp.no. Weight before	Weight before machining (g)	Weight after Weight before	material machining (g)	Time of experiment (min	TWR (g/min)
1	10.411	10.3914	0.0196	25	**0.415656**
2	10.392	10.3824	0.0096	25	0.415296
3	10.384	10.3746	0.0094	25	0.414984
4	10.372	10.3522	0.0198	25	0.414088
5	10.361	10.3414	0.0196	25	0.413656
6	10.348	10.3279	0.0201	25	0.413116
7	10.332	10.3157	0.0163	25	0.412628
8	10.325	10.3153	0.0097	25	0.412612
9	10.309	10.3003	0.0087	25	**0.412012**

Bold values indicate minimum and maximum range of MRR and TWR

5 Result and discussions

Mean of the GRG represents the significance level of process parameters. Significance of process parameters is represented by the difference between highest and lowest mean values of GRG. Greater difference will be of greater significance. From Table 13, duty cycle (η) contributes most significantly towards GRG; followed by pulse on time (Ton), peak current (Ip) and gap voltage (Vg). Among all the process parameters, duty cycle plays the most significant role in this experiment to optimize the MRR and TWR as per selected parameter range; this indicates that duty cycle is the most important parameter for the enhancement of MRR and decrement of TWR for developed carbon fibre material, we also find that during the pilot test selection of duty cycle is a very important step in the selection of suitable parameters. Mean effect plot of GRG with process parameters to represent the significant order is shown in Figs. 4, 5, 6 and 7. Significant order has shown the impact of different selected parameters in different designed experiments. Relation of different process parameters with GRG shown in main effect plot indicates that:

• With an increase in peak current (Ip), GRG increases up to level 2, and then it decreases.

• With an increase in gap voltage (Vg), GRG continuously increases up to level 3.

• With an increase in pulse on time (Ton), GRG first decreases up to level 2 and then increases up to level 3.

• With an increase in duty cycle (η), GRG continuously decreases up to level 3.

6 Conclusions

GRA provides an efficient method to find out good result for parametric design with less time in comparison with other optimization techniques. In this experiment for carbon nanotube (CNT)-reinforced 10-layered carbon fiber Nano composite as work material and copper–cadmium as tool following experimental result concluded

• Best possible optimum combination of process parameters is Ip2Vg3Ton1η1.

• Optimum MRR is 0.00004308.

• Optimum TWR is 0.411212.

• For the selected work material—carbon nanotube (CNT)-reinforced 10-layered carbon fiber Nano composite—duty Cycle (η) plays the most significant role and ranked 1 by GRG.

• Pulse on time (Ton) is a second significant factor.

• Peak current (Ip) ranked third according to the GRG,

• Gap voltage (Vg) marked as forth and plays least significant role for selected work material

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