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Investigation of Optimum Process Parameters Using Genetic Algorithm Based Neural Networks during EDM of 64WC-9Co

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Abstract

Conductive ceramics like cobalt bonded tungsten carbide which is categorized as with high mechanical and physical properties are usually known to create major challenges during conventional and non-conventional machining. Electrical discharge machining (EDM) which is very prominent amongst the non-conventional machining methods is expected to be used quite extensively in machining it due to the favorable features and advantages that it can offer.

This project was undertaken to study the machining performance of EDM with tungsten carbide using copper and graphite as electrodes. The effect of varying the machining parameters on the machining responses such as material removal rate (MRR), electrode wear ratio (EWR), was investigated. The experimental plan for both processes was conducted first on exploratory based and focused experiment conducted according to the design of experiments (DOE) and the results were statistically evaluated using analysis of variance (ANOVA). Taguchi methodology was employed in evaluating the machining performance of the SEDM process and mathematical models for MRR, EWR were developed. For verification of model results, conformation runs have been conducted. Results show that peak current was the most significant parameter that influenced the machining responses on EDM.

Artificial neural network and Genetic algorithm neural network based multi objective optimization implemented for maximization of MRR and minimization of EW has been done by using the developed empirical models. Optimization results have been used for identifying the effect of control parameters on responses that developed data sets which give the performance of parameters of SEDM on conductive ceramics.

Keywords: SEDM; Conductive ceramics; Taguchi; Artificial Neural Network; Genatic Algorithm.

1. Introduction

The advancements in material science introduced materials with high technological properties and made from inorganic primary substance named "Advanced Ceramics". In spite of their dominant technological properties, they have fractional acceptance in manufacturing industry due to difficulty in machining and high cost of processing. The new innovations in EDM technology allowed novel materials to be processed for high end application.

EDM is a specialized thermal machining process that utilizes non-contact technique by generating electrical spark at the electrode and work piece gap. Electrical Discharge Machining (EDM) is a well-known non-traditional machining process among manufacturers, especially in precision die and tool industries, who always try to emphasize for good desired accuracy and surface finish products. In this study, we are focused on the application of Sinking EDM (SEDM)

These new engineering materials satisfy the needs of high end applications in the areas of aerospace, automotive, defense, biological and nuclear fields. Engineering ceramic material composites have good servicing properties but difficult to machine. Traditional machining processes are unable to perform it, so many unconventional technologies like Electrical Discharge machining has proved to be effective tool in shaping such materials provided that the material should be conductive.

2. Literature Review

One of the first candidates for die-sinking applications on conductive ceramics is likely to be silicon carbide (SiC). It was performing by Ajmal in (1981).As the continuous evolution has been made to improve this limiting factor and researchers also take keen interest to improve the conductivity of oxide, non-oxide and composite based ceramics. By which the concept of doping carbides like TiC, NbC and Cr_3C_2 on oxide ceramics (ZrO_2-not conductive enough) so conductivity also increases and good finish rate is also achieved which investigated by S. Put et. Al.The general perception about the direction of study is from aspects related to the electrode, work piece material and surface quality attained after machining. But most of the studies by researchers are inclined towards monitoring and control of the process parameters.

2.1 Material Removal rate

The adequate selection of manufacturing conditions is one of the most important aspects to be taken into consideration while Sinking ED machining (SEDM) of conductive ceramics. This determines the characteristics of MRR. The manufacturing conditions can best be explained in terms of work-tool combination, electrode polarity, peak current, and pulse ON/OFF time, duty cycle factor, flushing pressure and process stability. I. Puertas and C. J. Luis have reported their investigation on various compositions of ceramics studying the significance of process parameters on MRR. They also developed methodology and strategy for maximum MRR

2.2 Electrode Wear Rate

The tool wear process (TWP) is quite similar to the material removal mechanism as the tool and work piece are considered as a set of electrodes in EDM. Generally, for EDM machining Copper, Graphite or Copper-tungsten electrodes are used. In electrode wear process C. J. Luis and. I. Puertas argued the three main factors that affect the Electrode Wear (EW) in descending order as intensity, pulse time and flushing pressure. Polarity selection is also important factor affecting on EW. I. Puertas in his work methodology for EDM of conductive ceramics established the tables for minimum wear strategy for EW by considering the influencing factors.

3. Experiment and Analysis

Design of Experiments (DOE) refers to planning, designing and analyzing an experiment so that valid and objective conclusions can be drawn effectively and efficiently. In performing a designed experiment, changes are made to the input variables and the corresponding changes in the output variables are observed. The input variables are called factors and the output variables are called response.

The experimental design summary is given on SEDM of cobalt boded tungsten carbide as work piece and copper as electrodes. Analysis and discussion are made on the MRR, EWR layer on both processes. The results are extracted from a series of experiment, based on the variation of machining parameters given in Table 1. The experimental plans for EDM process were based on the Taguchi design for both processes. The significant parameters that affected the machining work piece during the EDM were finding out by analyzing the process.

The results from the Table 1 were then input to the Design Expert software for further analysis according to the steps outlined for Taguchi design without performing any transformation on the responses, the revealed design status was evaluated, and all the information was used for further analysis.

Table 1: Design Summary of experiment runs.

Study Type	Factorial	Factors	Name	Units	Low Actual	High Actual	Levels
Initial Design	Taguchi OA	A	SG	Volt	50	62	2
Center Points	0	B	PC	Amp	9	17	3
Design Model	Main effects	C	OT	µs	93	360	3
Runs	18	D	DC	-	0.4	0.6	3

3.1 Equipment used in this experiment

All the experiments have been conducted on an AZ50 JOEMARS make Die Sinking Electrical Discharge Machine with z-axis NC fuzzy logic control. Figure 1 (a & b) shows the experimental set up of work piece and electrode along with SEDM machine. The dielectric has been jet flushed by nozzles, directed against the arc gap under 0.5 kg/cm^2 pressure.WC-C0 as a work piece which is a specimen in cremate size and electrolyte copper as a tool has been used which work as a negative polarity material.

4. Parametc Analysis

An ANOVA (analysis of concludes information of analysis of variance and case statistics for further variance) table is commonly used to summarize the experimental results

4.1 Analysis on MRR

Table 2: ANOVA table for MRR in EDM Cu to Rp-30 process.

Source	DF	Seg SS	Adj SS	Adj MS	F	P
SG	1	0.150	0.1495	0.1495	0.05	0.831
PC	2	93.305	93.3050	46.6525	15.04	0.001
OT	2	1.442	1.4420	0.7210	0.23	0.797
DC	2	0.719	0.7186	0.3593	0.12	0.892
Residual Error	10	31.009	31.0092	3.1009		
Total	17	126.624				

An ANOVA (analysis of concludes information of analysis of variance and case statistics for further variance) table is commonly used to summarize the experimental results. Table 5.3 shows the ANOVA table for MRR after transformation and generated by the Minitab 15 software

4.2 Analysis on EW

Table 3: ANOVA table for EW in EDM Cu to Rp-30 process.

Source	DF	Seg SS	Adj SS	Adj MS	F	P
SG	1	80.60	80.60	80.597	9.15	0.013
PC	2	60.26	60.26	30.130	3.42	0.074
OT	2	23.52	23.52	11.760	1.34	0.306
DC	2	26.04	26.04	13.020	1.48	0.274
Residual Error	10	88.04	88.04	8.804		
Total	17	278.45				

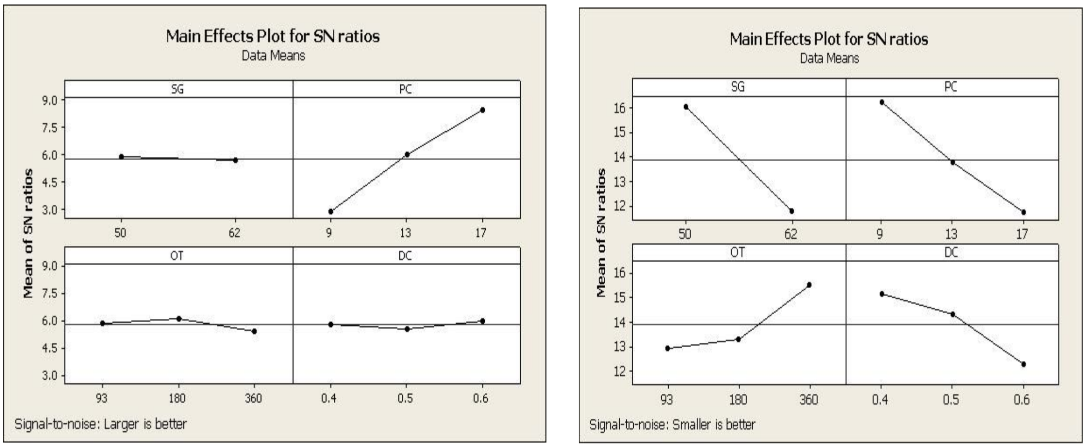

Figure 1: Main Effects Plot for MMR and EW for Cu to Rp-30.

Figure 1 revealed the main effects plots the purpose of this analysis is to find out the strong effect of parameters on MRR .It shows the A1, B3, C2 and D3 have strong effect on maximizing the MRR. As observed in the ANOVA table 3, the factors that influence the EW are All four but the most two effectives are A and B and all significant effect of it shown graphically in figure 1 where the interaction of above parameters and effect of it MRR and EW can be visualize.

5. Optimization Using GABPN

In EDM process, it is difficult to find a single optimal combination of process parameters for the performance parameters, as the process parameters influence them differently .Hence, there is a need for a multi –objective optimization method to arrive at the solution to this problem because classical methods fro solving it suffer from drawback and also it fails when function becomes discontinuous.

To perform the optimization process following steps has been taken into procedure (1) There are four variables with different level and the variables are (i) Peak current, (ii) ON time, (iii) Duty Cycle, (iv) Sparking Gap by which the chromosome length is 4. (2) The initial Population P0 of 500 and it is randomly generated chrosomosome (3) Compute the input hidden layer weights and the hidden output layer weights extracted. (4) Computehe individual fitness for chromosome (5) Create mating pool so duplicate worst fit chromosome with best fit chromosome and Reproduction of population by applying the cross over rate (6) Computation of fitness value by given fitness function (7)Check the convergence.

Table 4: Parameters set for GANN.

Parameters	Uncoded Value	Coded Value
SG	50 62	-1 1
PC	9, 13 , 17	1 0 -1
OT	93, 180, 360	1 0 -1
DC	0.4, 0.5, 0.6	1 0 -1

The GANN predicted results are in good agreement with compare to only ANN model so the more optimized result values can be obtained from GANN model and the predicted error will be reduced and more optimizes network can be used for production

6. Conclusions

An extensive experimental study has been conducted to investigate the effect of the machining parameters on machining characteristics in EDM of tungsten carbide. The machining parameters are the electrode material, electrode polarity, gap voltage, peak current, pulse duration, pulse interval and flushing. The machining characteristics are the material removal rate, relative wear ratio and surface roughness. Tentatively, the following conclusions may be drawn from the study.

1) For all electrode materials, the material removal rate increases with increasing peak current.
2) The material removal rate generally decreases with the increases of gap voltage, whereas the relative wear ratio increase with the increase of gap voltage.
3) There is a maximum material removal rate with pulse ON time at all current settings. The relative wear ratio increases with increase in pulse duration for all peak current settings
4) The GA developed based on neural network is good at automatically selecting an optimal process parameter set in accordance with the desired machining performances.

5) There is considerable reduction in data error when the network is optimized with GA tool.

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