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Research Article

Optimization of ECM Process Parameters for TiC Composite using GRA

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Abstract

A suitable selection of machining parameters for the electrical discharge machining process relies heavily on the operators' technologies and experience because of their numerous and diverse range. Environmental sustainability in machining requires that the energy and carbon footprint of machined products be optimize Hence machining becomes inevitable. In this work, machinability behavior of different combination of machining parameter is using on TiC during Electric Chemical Machining. The input parameters of the GRA model are Feed Rate (mm/min) Flow rate (l/min), Electrolyte Concentration (g/l). The output parameters of the model are MRR, and Overcut. it depicts percentage contribution of each factor with respect to over cut and it depicts that electrolyte flow rate and electrolyte concentration are contributing factor more and tool feed rate plays nominal role with respect to overcut and MRR.

Keywords: *ECM, Electrolyte, GRA, Orthogonal array*

1. Introduction

Electrochemical Machining (ECM) is a non-traditional machining (NTM) process belonging to electrochemical category. ECM is opposite of electrochemical or galvanic coating or deposition process. Thus ECM can be thought of a controlled anodic dissolution at atomic level of the work piece that is electrically conductive by a shaped tool due to flow of high current at relatively low potential difference through an electrolyte which is quite often water based neutral salt solution. Electrochemical machining (ECM) was developed to machine difficult-to cut materials, whose laws were established by Michael Faraday.

2. Methodology

Traditional experimental design procedures are too complicated and not easy to use. To solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameters with small no of experiments. In is addition to the S/N ratio, a statistical analysis of variance (ANOVA) is employed to indicate the impact of process parameters on material removal rate and on overcut. Finally the grey relation analysis is used for analyzing the relationship between the ECM input parameters and responses. The ECM process is intrinsically nonlinear and additionally is a high coupled multivariable system. Due to restrictions of the grey relation analysis, the formulas may cause significant imprecision in the fitting results.

Table 1 Factors and Levels Selected for ECM of TiC

Factor	Process Parameter	Level 1	Level 2	Level 3
A	Feed rate(mm/min)	0.10	0.15	0.20
B	Electrolyte flow(lit/min)	0.65	0.75	0.95
C	Electrolyte concentration (%)	16	20	24

Table 2 Experimental Observations Using L27 Orthogonal Array (Tic)

Ex. No	A	B	C	MRR	Overcut
1	0.1	0.65	16	0.040435	1.221972
2	0.1	0.65	20	0.055627	1.22404
3	0.1	0.65	24	0.070819	1.226108
4	0.1	0.75	16	0.039233	1.324572
5	0.1	0.75	20	0.054425	1.32664
6	0.1	0.75	24	0.069617	1.328708
7	0.1	0.95	16	0.036829	1.529772
8	0.1	0.95	20	0.052021	1.53184
9	0.1	0.95	24	0.067213	1.533908
10	0.15	0.65	16	0.042625	1.300872
11	0.15	0.65	20	0.057817	1.30294
12	0.15	0.65	24	0.073009	1.305008
13	0.15	0.75	16	0.041423	1.403472
14	0.15	0.75	20	0.056615	1.40554
15	0.15	0.75	24	0.071807	1.407608
16	0.15	0.95	16	0.039019	1.608672
17	0.15	0.95	20	0.054211	1.61074
18	0.15	0.95	24	0.069403	1.612808
19	0.2	0.65	16	0.044815	1.379772
20	0.2	0.65	20	0.060007	1.38184
21	0.2	0.65	24	0.075199	1.383908
22	0.2	0.75	16	0.043613	1.482372
23	0.2	0.75	20	0.058805	1.48444
24	0.2	0.75	24	0.073997	1.486508
25	0.2	0.95	16	0.041209	1.687572
26	0.2	0.95	20	0.056401	1.68964
27	0.2	0.95	24	0.071593	1.691708

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Table 3 Optimum Level Selection TiC

Level	A	B	C
1	0.616797	0.68848	0.4704
2	0.56387	0.575369	0.5409
3	0.539759	0.4565	0.708941
Delta	0.077038	0.23198	0.238541
Rank	3	2	1

3. Effect on MRR (Tic)

The Fig.1 shows the main effects plot for material removal rate increases with increasing in electrolyte concentration mostly, since the current density is proportional to the concentration of electrolyte, and the electrolyte flow rate made difference in material removal rate and feed rate contributes fewer amounts in material removal rate.

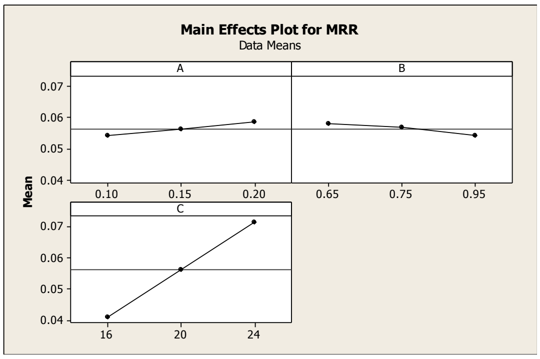

Fig. 1 Main Effects Plot for M.R.R of TiC

The formation of oxide film on the metal surface hinders efficient ECM and deep grain boundary attack of the metal surface can occur and leads to poor surface finish Material removal rate have the higher the better criterion. The S/N ratio of responses is computed by using statistical software. The S/N graph plot for material removal rate is shown in fig.2. Material removal rate increases with increasing in electrolyte concentration. Hence S/N ratio is used considering the MRR as performance index. Based upon the experimental result exhibited in Table 2, the influences of various process parameters on material removal rate and overcut has been analyzed.

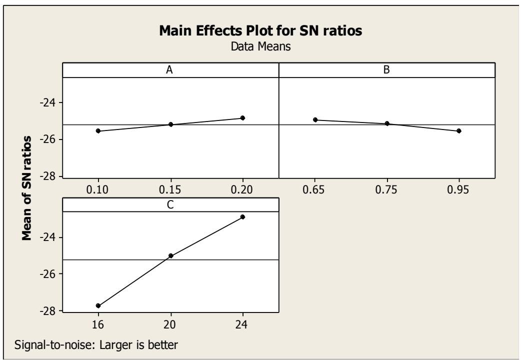

Fig. 2 S/N Graph for M.R.R in TiC

Table 4 Analysis of Variance for TiC

Source	DOF	Sum of squares (S)	Variance (v)	F Ratio	P value	Contribution (%)
A	2	0.0000621	0.0000312	24.47	0.039	3.77
B	2	0.0000872	0.0000437	34.31	0.028	5.29
C	2	0.0014974	0.0007492	587.9	0.002	90.77
Error	2	0.0000025	0.0000013	……..	……	……….

Influence of a factor on a particular output response could be revealed by this method. The conventional way of looking into the averages of results to know the desirable factor levels. For higher productivity, a higher material removal rate is always desired; hence, MRR has been categorized as 'larger-the-better' type problem. The signal-to-noise ratio in this case has been calculated as follows.

S/N of MRR = -10log10 (square reciprocal of MRR)

The response table shows the average of selected characteristics for each level of the factor. This table includes the rank based on delta statistics, which compare the relative values of the effects.

Table 5 shows Taguchi analysis response for material removal rate. In summary, the optimal combination level of the machining parameters isA3B1C3.ie, (Exp. No.7) with feed rate 0.20 mm/min, flow rate of 0.65 lit/min and Electrolyte conc. of 24%.

Table 5 Taguchi Analysis Response Table for MRR LARGER IS BETTER (TiC)

Level	A	B	C
1	-25.59	-24.97	-27.75
2	-25.23	-25.16	-25.01
3	-24.88	-25.56	-22.93
Delta	0.71	0.59	4.82
Rank	2	3	1

The contribution of parameters on material removal rate is identified using ANOVA and presented in Table 6 and it depicts percentage contribution of each factor with respect to MRR. Electrolyte concentration is more contributing factor for material removal rate followed by electrolyte flow rate and feed rate.

Table 6 ANOVA for M.R.R (TiC)

Source	DOF	Sum of squares (S)	Variance (v)	F Ratio	P value	Contribution (%)
A	2	0.0000621	0.0000312	24.47	0.039	3.77
B	2	0.0000872	0.0000437	34.31	0.028	5.29
C	2	0.0014974	0.0007492	587.9	0.002	90.77
Error	2	0.0000025	0.0000013	……..	……	……….
Total	8	0.0016492	………	……..	……	…………

3. Effect on Overcut

A lower overcut is always intended in production environment. Overcut is the smaller the better criterion. The main effect plot for over cut is shown in fig. 3 and it depicts that, the over cut increases with increasing at the same time it decreases with increasing electrolyte flow and electrolyte concentration.

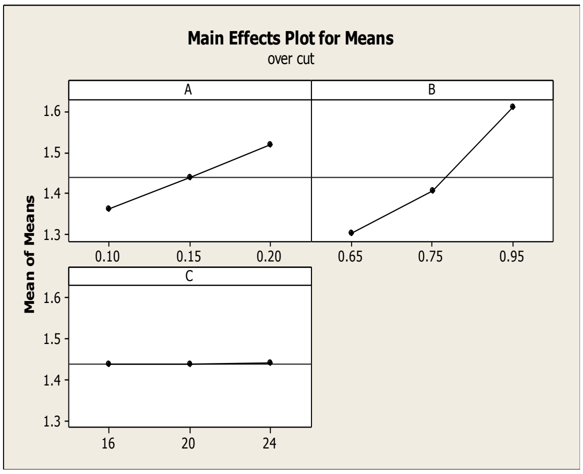

Fig. 3 Main effect Plot for OC.

Table 7 ANOVA for Overcut diameter

Source	DOF	Sum of squares (S)	Variance (v)	F Ratio	P value	Contribution (%)
Feed Rate	2	0.061	0.03	16.71	0.056	25.94
Flow Rate	2	0.162	0.081	44.62	0.022	69.25
Elec. Conc.	2	0.008	0.004	2.1	0.323	3.25
Error	2	0.004	0.002	……..	……	………
Total	8	0.234	………	……..	……	………..

The contribution of both parameters overcut and MRR are identified using ANOVA and presented in Table 7 and it depicts percentage contribution of each factor with respect to over cut and it depicts that electrolyte flow rate and electrolyte concentration are contributing factor more and tool feed rate plays nominal role with respect to overcut and MRR electrolyte flow rate (52.47%) influences more on machining Tic followed by electrolyte concentration (29.69%) and feed rate (14.08%).

Conclusions

Experimental works were done on TiC material by using Taguchi L9 orthogonal array. By using the ANOVA technique most significant factor on output responses were studied. By using S/N ratio analysis we found the optimum level for each factor that would lead us to optimum machining condition to obtain an optimum level in achieving high material removal rate, minimize OC-diameter. The following conclusions are arrived. Overcut is most affected by electrolyte concentration and by flow rate, least affected by feed. Overcut is decreases with decreasing feed and electrolyte flow rate. Statistical results show that the feed rate, electrolyte flow rate and electrolyte concentration affects the material removal rate by 3.77%, 5.29%, 90.77%. Statistical results show that the feed rate, electrolyte flow rate and electrolyte concentration affects the overcut by 25.94%, 69.25%, 3.25%.

The maximum material removal rate is obtained as 0.0805g/min and overcut as 1.230mm by optimum machining condition. From the grey relation grade the optimal machining parameter settings are obtained for TiC is feed 0.10mm/min, 0.65lit/min and electrolyte concentration 24%. Material removal rate is mostly affected by electrolyte concentration and least affected by feed rate.

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