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EXPERIMENTAL INVESTIGATION OF MACHINING PARAMETERS FOR EDM OF "ZA-27" ALLOY USING TAGUCHI ANALYSIS

OPTIMIZATION OF ELECTRIC DISCHARGE MACHINING FOR "ZA-27" ALLOY USING TAGUCHI ANALYSIS

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Abstract- Electrical Discharge Machining (EDM) is capable of machining geometrically complex or hard material components, that are precise and difficult-to-machine such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. being widely used in die and mold making industries, aerospace, aeronautics and nuclear industries. In the present work ZA-27 alloy is used as work piece which was machined by different electrode materials such as copper, graphite and brass. Machining parameters used were type of electrode, current and pulse on time. And the output parameters found were MRR and TWR. The settings of machining parameters were designed according to Taguchi's L9 orthogonal array and significant machining parameters were identified using Signal to noise ratios and ANOVA. The results reveal that high material removal rate was achieved by increasing the current, and less tool wear was found for copper electrode.

Keywords- Electrical discharge machining (EDM), ZA-27 alloy, Taguchi method, L9 orthogonal array, Signal to noise ratios (S/N ratios), ANOVA.

I. INTRODUCTION

It is clear that the past few years have seen an increasing interest in the novel applications of electrical discharge machining to see the potential of this technique for better process performances it is obvious that lot of work has been done to optimize the EDM process and the work related to finding the feasibility of harder material. The correct selection of manufacturing conditions is one of the most important aspects to take into consideration in the majority of manufacturing processes and particularly, in processes related to Electrical Discharge Machining (EDM). It is a capable of machining geometrically complex or hard material components, that are precise and difficult-to-machine such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. being widely used in die and mold making industries, aerospace, aeronautics and nuclear industries. Distinguishing features of ZA-27 alloys include high cast strength, excellent bearing properties, as well as low energy requirements for melting. Rajaneesh N. Marigoudar et al [1] in his study, ZA43 reinforced with SiC is machined by wire EDM process. It was observed that applied current and pulse on time increases the material removal rate where as pulse off time has less effect on it. K.S.Banker et al [2] the performance capabilities of the EDM process by using different electrode materials has been carried out. Despite a range of different approaches, this new research shares the same objectives of achieving more efficient metal removal coupled with a reduction in tool wear and improved surface quality.

Subramanian Gopalakannan et al [3] in his study, the effect of pulsed current on material removal rate, electrode wear, surface roughness and diameteral overcut in corrosion resistant stainless steels viz., 316 L and 17-4 PH. The materials used for the work were machined with different electrode materials such as copper, cop-per-tungsten and graphite. It is observed that the output parameters such as material removal rate, electrode wear and surface roughness of EDM increase with increase in pulsed current. The results reveal that high material removal rate have been achieved with copper electrode whereas copper-tungsten yielded lower electrode wear, smooth surface finish and good dimensional accuracy. Kamlesh V. Dave et.al [4] found that the tool electrode in EDM process is the means of providing electrical energy to the work piece. The contribution of Tool Geometry was found a significant factor on the Surface Roughness and Material Removal Rate (MRR). Nikhil Kumar et al [5] in his paper, Die- Sinker EDM using copper and graphite electrode experiment has been done for optimizing Performance parameters and reducing cost of manufacturing, finally it is found that a silver electrode give better performance in certain characteristics but the cost become high for machining so keeping in mind cost and other characteristics a graphite electrode is more suitable than copper electrode in case of both MRR and TWR.

Rajesh et al. [6] Concluded that the machining time (MT) mainly affected by wire tension (WT). Voltage (V) has less effect on it. Voltage gap (V_g) and current (I) has a least effect on MT. The surface roughness (SR) is mainly influenced by wire tension (WT). The effect of voltage gap (V_g) and voltage (V) is less on SR and current (I) has least effect on AA alloy 6061 T6. Sohani et al. [7] Presented about sink EDM process effect of tool shape and size factor are to be considered in technique using RSM process parameters like discharge current (Ip), pulse on- time (Ton), pulse off time (Toff), and tool area. The RSM-based mathematical models of Metal Removing Rate (MRR) and Tool Wear Rate have been produced using the data got through central composite design (CCD). The analysis of variance is applied to check the lack of fit and adequacy of the developed models. The investigations showed that the best tool shape for higher MRR and lower TWR is circular, then triangular, then rectangular, and lastly square cross sections. Santanu Dey Dr. D.C.Roy et al [8] At the initial stage MRR using graphite electrode is more as compare to copper electrode, which implies that at low current, impulse duration and spark gap using graphite electrode is more economical. But as the value of the parameters increases, MRR with copper electrode increases more rapidly in respect of graphite electrode. He concluded that graphite electrodes are best suitable for lower values of parameters and mainly for finishing work as graphite electrode produces better surface finish due to lower MRR and copper electrodes are suitable for high metal removal process where finish requirements are not significance. The MRR is found to increase in an almost linear fashion with increase in current for constant gap voltage and Pulse on time. MRR is also found to increase slightly with increase in Pulse duration. Harprit singh et al [9] Concluded that Material removal rate is increased with increase in pulse off time material removal rate is decreased with increase in pulse on time in case of brass electrode and decrease in cooper electrode

II. EXPERIMENTAL PROCEDURE

Experiments were conducted on the electrical discharge machine model V5030 from VM Engineer, Bangalore (die-sinking type) with servo head and positive polarity for electrode was used to conduct the experiments. Commercial grade EDM oil (specific gravity= 0.763, freezing point= 94°C) was used as dielectric fluid. The workpiece material used in this study was ZA-27 alloy, which is developed to compete with bronze, cast iron and aluminium. Zinc Aluminium alloy has following key advantages precision tolerance, process flexibility, good strength and ductility, anti sparking, excellent bearing properties, thin wall castability, rigidity etc. Complex shapes required for dies can be achieved by EDM of ZA-27 alloy. Three different electrodes were used as a machining parameter other 2 parameters are Current (A) and Pulse on time (μs) for the optimization of output parameters as material removal rate (MRR) and tool wear rate (TWR). Experiments were conducted using *L*9 orthogonal array, of Taguchi method. The machining parameters and their levels are highlighted in Table 1.

Parameters considered constant are electrode diameter 14mm, voltage 40-45 volts, machining time duration i.e.5mins, pulse of time 5μs.

Table 1: Parameters & their levels in experimental setup

Machining parameter	Symbol	Unit	Level

Electrode type	-	-	Cu	Gr	Br
Current	A	Amps	6	12	24
Spark on time	Ton	µs	5	7	9

2.1 Selection of workpiece:

Chemical composition analysis of ZA-27 alloy, was done by Jyothi Spectro Analysis Pvt. Ltd. Hyderabad

Table 2: Composition of Zinc Aluminium Alloy

Component	**Wt. %**
Al	29.069
Cu	03.28
Fe	0.122
Pb	0.249
Cd	0.011
Mg	0.049
Mn	0.018
Sn	0.010
Zn	67.192

Table 3: Physical properties of Zinc aluminium alloy

Physical Properties	**Metric**
Density	4.60 g/cc
Brinell Hardness	111
Ultimate Tensile Strength	322 MPa

The standard L9 array with 3 parameters and 3 levels is shown in the table is applied in the experiment

Table4: Standard L9 array

EXPERIMENT	P1	P2	P3
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

III. DESIGN AND PLAN OF THE EXPERIMENTS

To evaluate the effects of the machining parameters on the performance characteristics, a specially designed experimental procedure is required. Classical experimental design methods are too complex and difficult to use. Additionally, a large number of experiments have to be carried out when the number of machining parameters increases. In this study, the Taguchi method, a powerful tool for the parameter design of performance characteristics, was used to determine the optimum machining parameters for the maximum MRR, the minimum TWR by electrical discharge machining (die-sinking type).The methodology of Taguchi for three factors at three levels was used for the implementation of the plan of the experiments.

A Taguchi design or an orthogonal array the method is designing the experimental procedure using different types of design like, two, three, four, five, and mixed level. In the study, a three factor mixed level setup is chosen with a total of 9 numbers of experiments to be conducted and hence the orthogonal array L9 was chosen. It was decided to utilize the L9 setup, which in turn would reduce the number of experiments at the later stage. In addition, the comparison of the results would be simpler. The optimization of the observed values was then determined through a comparison with the Taguchi's signal-to-noise(*S/N*)ratio.

Material removal rate (MRR):

MRR is expressed as the ratio of the difference of weight of the work piece before and after machining to the machining time.

$$\text{MRR} = \frac{Wi - Wf}{\rho * t}$$

Where,
W_i is the weight of the work piece before machining,
W_f is the weight of the work piece after machining
t is the machining time (5min const.)
ρ is density

Tool wear rate (TWR) :

TWR is expressed as the ratio of the difference of weight of the tool before and after machining to the machining time.

$$\text{TWR} = \frac{Wtb - Wta}{\rho * t}$$

Where,
W_{tb} is the weight of the tool before machining,
W_{ta} is the weight of the tool after machining, and
t is the machining time (5min const.)
ρ is density of tool used

IV. RESULT AND DISCUSSION

In order to improve machining efficiency, reduce the machining cost, and improve the quality of machined parts, it is important to select the most appropriate process parameter conditions in a machining operation. The analysis of variance (ANOVA) was used to establish statistically significant machining parameters and the percent contribution of these parameters on the workpiece surface roughness. In Taguchi method, a loss function is used to calculate the deviation between the experimental value and the desired value. This loss function is further transformed into a signal-to-noise (S/N) ratio. There are several S/N ratios available depending on type of characteristics; larger the better (LB), nominal the best (NB), or smaller the better (SB).

The *S/N* ratio based on the larger-the-better criterion for MRR was calculated using the following equation:

S/N = -10 Log_{10} [mean of sum squares of reciprocal of measured data]

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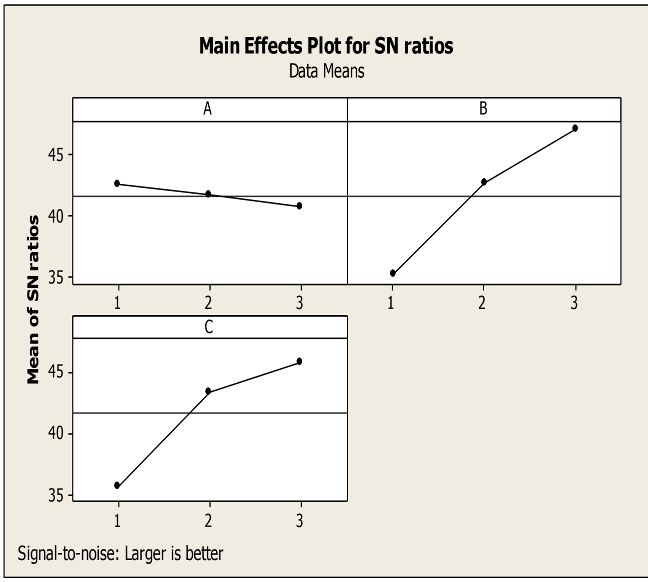
The *S/N* ratio based on the smaller-the-better criterion for the overall grey relational grade was calculated by using the following equation:

S/N = -10 Log_{10} [mean of sum of squares of measured data]

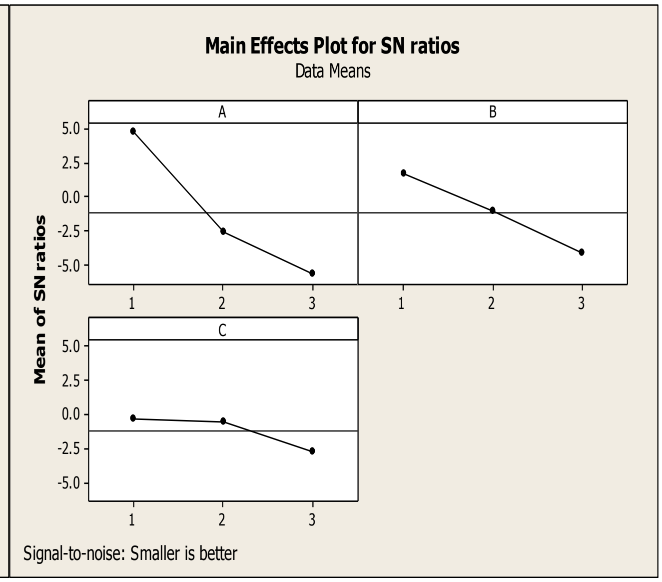
Table 5: Response Table:

RUN	ELECTRODE	CURRENT	TON	MRR	S/N	TWR	S/N
1	Cu	6	5	36.52174	31.2510	0.336	9.47321
2	Cu	12	7	173.7826	44.8001	0.6056	4.35055
3	Cu	24	9	372.53	51.4232	0.942	0.51898
4	Gr	6	5	65.2697	36.2942	0.879	1.12022
5	Gr	12	7	252.4583	48.0437	1.428	-3.0945
6	Gr	24	9	106.2172	40.5238	1.978	-5.9245
7	Br	6	5	79.43202	37.9999	1.917	-5.6524
8	Br	12	7	57.26495	35.1577	1.684	-4.5268
9	Br	24	9	283.246	49.0432	2.245	-7.0243

Graph 1: Main effects plot for MRR



Graph 2: Main effects plot for TWR



3(b)

4.1 Analysis of variance (ANOVA):

ANOVA method was developed by Sir Ronald fisher in the 1930s as a way to interpret the results from the agricultural experiments. Anova is carried out to find the relative significance of the various process parameters on the output parameters. Anova is a statistically based, objective decision making tool for detecting any differences in average performance of groups of items tested. The decision, rather than using pure judgment, takes variation into account.

Analysis of variance can be used to test whether the mean (or median) of a variable differs among three or more groups.

Table 6: ANOVA test for MRR

Source of variation	Sum of squares	Degrees of freedom	Mean square	F_0	C(%)	Rank
Electrode	4.63495	2	2.317474	2.267668	1.174795	3
Current	214.37397	2	107.187	104.8834	54.3362	1
Ton	169.39182	2	84.69591	82.87566	42.93482	2

Error	6.1318	6	1.021964		1.554189	
Total	394.53254	8	49.31656		100	

Table 7: ANOVA test for TWR

Source of variation	Sum of squares	Degrees of freedom	Mean square	F_0	C(%)	Rank
Electrode	175.2286	2	87.61428	70.58033	71.85819	1
Current	50.34221	2	25.17111	20.27735	20.64447	2
Ton	10.83447	2	5.417237	4.364019	4.44303	3
Error	7.448048	6	1.241341		3.054315	
Total	243.8533	8	30.48166		100	

Referring table 6 it is noticed that factor current has largest contribution to the total sum of squares i.e. 54.3362% for Material removal rate. It was also found that in case of MRR, Type of Electrode chosen is has having least contribution of 1.174%, and pulse on time is intermediate with contribution of 42.934%.

Referring table 7, the type of Electrode chosen is having largest contribution to the total sum of square i.e. 71.85819% for TWR. The factor current is having contribution of 20.644 %.The least with pulse on time with a contribution of 4.443%. If many components require EDM machining in that case we can consider more durable electrodes i.e. tungsten based electrodes can be used.

V. CONCLUSIONS

- For MRR, after the Taguchi analysis taking larger is better for the Signal to noise ratio from equation $n = -10 \text{ Log}_{10}$ [mean of sum of squares of reciprocal of measured data] and we get results as current is the most significant factor for Material Removal Rate. This may be noted on graph and analysis result to first rank.
- For TWR, after the Taguchi analysis taking smaller is better for Signal to noise ratio from the equation $n = -10 \text{ Log}_{10}$ [mean of sum of squares of measured data] and we get results as Type of Electrode used is the most significant factor for Tool Wear Rate.
- Finally, it can be concluded that graphite electrodes are best suitable for lower values of parameters and mainly for finishing work as graphite electrode produces better surface finish.
- Copper electrodes are suitable for high metal removal process where finish requirements are not significant.
- Zinc Aluminum alloy has low density. This makes handling of the tooling and molds easier, and allows faster opening and closing of molds.
- Can be machined and polished more rapidly. Depending on the specific Zinc aluminum alloy, machining rates three to ten times faster than that for steel are possible. This reduces the time required for mold production, particularly for large molds with deep cavities.
- Exhibits high electrical conductivity. This, along with a lower melting point as compared to steel, enables the use of electrical discharge machining of ZA27 at a rate four to five times higher than for steel.

REFERENCES

[1] Rajaneesh N. Marigoudar, Kanakuppi Sadashivappa, "Effect of Machining Parameters on MRR and Surface Roughness in Machining of ZA43/ SiCp Composite by WEDM," International Journal of Applied Science and Engineering,2013. 11, 3: 317-330.

[2] K.S.Banker, A.D. Oza, R.B. Dave, "Performance Capabilities of EDM machining using Aluminum, Brass and Copper for AISI 304L Material," International Journal of Application or Innovation in Engineering & Management (IJAIEM), Volume 2, Issue 8, August 2013, ISSN 2319 – 4847.

[3] Subramanian Gopalakannan, Thiagarajan Senthilvelan, "Effect of Electrode Materials on Electric Discharge Machining of 316 L and 17-4 PH Stainless Steels," Journal of Minerals and Materials Characterization and Engineering, 2012, 11, 685-690.

[4] Kamlesh V. Dave, D. S. Patel, "Effect of Tool geometry and Process parameters on Surface roughness and MRR in EDM of Tool Steel," International Journal of Engineering Research &Technology (IJERT) Vol. 1 Issue 5, July 2012 ISSN: 2278-0181

[5] Nikhil Kumar, Lalit Kumar, Harichand Tewatia, Rakesh Yadav, "Comparative Study for MRR on Die-Sinking EDM Using Electrodes of Copper and Graphite," International Journal of Advanced Technology & Engineering Research (IJATER), ISSN NO: 2250-3536

[6] Rajesh.S, Vinitesh.K.V, Lingaraju.K.N "Process optimization on CNC WEDM for Al-6061 Material using Taguchi Technique to Enhance Surface Finish and Machining Time," Dept. of Mechanical Engineering, Govt. Engineering College. Chamarajanagar

[7] Sohani, M.S., Gaitonde, V.N., Siddeswarappa, B. And Deshpande, A.S., "Investigations into the effect of tool shapes with size factor consideration in sink Electrical Discharge Machining (EDM) Process," International Journal of Advanced Manufacturing Technology, 2009.1-15

[8] Santanu Dey, Dr. D.C.Roy, "Experimental Study Using Different Tools/Electrodes E.G. Copper, Graphite on M.R.R of E.D.M Process and Selecting The Best One for Maximum M.R.R in Optimum Condition," International Journal of Modern Engineering Research (IJMER) www.ijmer.com Vol.3, Issue.3, May-June. 2013 pp-1263-1267

[9] Harpreet Singh, Amandeep Singh "Effect of Pulse On, Pulse off Time on Machining of AISI D3 Die Steel Using Copper and Brass Electrode in EDM," International Journal of Engineering and Science ISSN: 2278-4721, Vol. 1, Issue 9(November 2012), PP 19-22

