PARAMETRIC ANALYSIS ON ELECTRO - DISCHARGE MACHINING (EDM) OF INCONEL 825 SUPER ALLOY USING TAGUCHI TECHNIQUE

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Abstract: Optimization is one of the techniques used in manufacturing sectors to arrive for the best manufacturing conditions, which is an essential need for industries towards manufacturing of quality products at lower cost. This project aims to investigate the optimal set of process parameters such as Inter-Electrode Gap (IEG), pulse on time (Ton) and pulse off time (Toff) in Electrical Discharge Machining (EDM) process to identify the variations in their performance characteristics such as rate of material removal (MRR) and wear rate on tool (TWR) on the work material for Inconel 825 super alloy using copper as an electrode. Based on the experiments conducted on L9 orthogonal array developed using MiniTAB tool, analysis has been carried out using Taguchi method. Response tables such as Analysis of Variance tables (ANOVA) and S/N (Signal to Noise) ratio graphs were used to find the optimal levels of parameters in EDM process. Thus, by using Taguchi technique, the machining parameters for EDM were optimized for achieving the combined objectives of maximizing the rate of material removal and minimizing the wear rate on tool on the work material have been considered in this work.

Keywords: *Material removal rate, tool wear rate, EDM, Taguchi technique, Optimization.*

I. Introduction

Electrical discharge machining (EDM) is the widely used non traditional method. However, machining of these surfaces consumes more time because of the low material removal rate (MRR). Over the past few years, researchers have worked for improving the efficiency of the EDM process. An alternative method to improve efficiency was discovered by adding metal powder or alloy powder to the dielectric fluid. Proper input parameter values have been set for a particular combination of work piece tool materials to optimize the EDM output performance; however, many researchers have carried out to determine optimal process parameters. The EDM process has many variables, which makes it difficult to attain an optimal set of input parameters. This has resulted in an increase in the cost of research work and studies. To ensure the economic efficiency of technical research in the EDM field, many different experimental design methods have been tested, including full factorial design, response surface methodology and Taguchi methods. The effect of the electrical conductivity of the powder mixed into the dielectric fluid has been examined by many researchers. The chromium powder concentration (2 to 6 gram/litre), electrical discharge intensities and electrode size were the parameters that strongly influence the MRR and tool wear rate (TWR) [1]. Graphite powder (10 µm, 4 gram/litre) mixed in the dielectric fluid increases and decreases the MRR and TWR by 68 % and 28 %, respectively. [2]. The surface roughness (R_a) and other surface properties of H13 steel were found to be affected by the electrode size in PMEDM using silicon powder [3, 4]. An increase in electrode size increases the R_a and alters the thickness of the white layer. Machining have been done on EN24 tool steel to obtain increased MRR and reduced TWR by varying the parameters using Taguchi techniques and have proved that the pulse current has more effect on the output characteristics [5]. Many trials have been conducted on DS-EDM in Inconel 825 alloy by employing nickel plated copper electrode with straight polarity and have reported that the applied current has serious effect on obtaining the optimized surface roughness [6]. Boric acid (H_3BO_3) powder had a milder effect on the R_a, MRR and TWR than graphite (Gr) powder [7]. Increasing the concentration of boric acid powder results in an increase in the MRR and microscopic surface hardness and reduces the TWR and R_a. Using aluminum powder (300 – 400 µm) increases the MRR and decreases the TWR and R_a; this improves the productivity and quality of the machining process [8]. Concentration of the silicon powder and intensity of the electrical discharge are parameters that strongly influence the MRR [9]. When Gr powder is used, the TWR of thermally treated copper is lower than that of non-thermally treated copper [10]. The influence of the process parameters on the MRR and TWR as well have been investigated using Taguchi methods.

II. Experimental Procedure

From the literature survey, it has been observed that considerable work has been done on various aspects of electrical discharge machining on super alloys. There is a need to investigate the machining of this material with copper electrode and using EDM oil as dielectric fluid by varying different machining parameters like inter electrode gap (IEG), pulse on time and pulse off time. Inconel 825 super alloy (Dimensions: 62.5 mm x 50mm x 10mm, and Composition: C=0.05%, Mn=1.0%, Si=0.50%, Cr=20%, Ni=45%, Mo=3%, Ti=1.1%, Cu=1.5%, S=0.03%, Fe=remaining %) is selected as work material because of its excellent resistance to acids, good wear resistance and high compressive strength. The electrode material selected for the present work is copper (99.99% Cu) electrode. Experiments have been performed on Sparkonix S25/50 ZNC EDM with newly designed experimental setup consisting of mild steel tank placed in the work tank. Various machining conditions used during experimentation are listed in table 1. In this work, 9 experiments were conducted at the stipulated conditions and their levels were given in table 2 and the main objective of this paper is to maximize the material removal rate (MRR) and to minimize the tool wear rate (TWR).

Table 1: **Machining conditions**

Tool	**Copper**
Work piece	**Inconel 825 Super alloy**
Polarity	**Positive**
Time of trial	**15 mins**
Dielectric	**EDM Oil**
Voltage	**60 V**

Table 2: **Parameters and levels**

Parameters	**Level 1**	**Level 2**	**Level 3**
Pulse on time (µs)	100	200	300
Pulse off time (µs)	20	30	40
IEG (mm)	0.1	0.2	0.3

III. Machining responses

Material removal rate (MRR) and tool wear rate has been selected as the output response in this research work and the formula for calculating the MRR and TWR has been shown in eqn (1) and eqn (2), respectively. MRR is defined as the total weight of the material removed or machined to the machining time.

MRR = [(Initial – Final) weight / time] (1)

Similarly, the tool wear rate is nothing but the amount of tool removed during machining and it has been calculated using

TWR = [(Initial – Final) weight / time] (2)

IV. Results and Discussions

After experimentation, the analysis and discussion of results have to be carried out. In this section the effect of input parameters such as IEG, pulse on time and pulse off time on MRR and TWR was presented. The plots showing the effect of parameters on responses have drawn accounting the effect of all factors. Table 3 shows the input parameters and their responses.

Table 3: **Input parameters with their responses**

Parameters	Pulse on time	Pulse off time	IEG	MRR (g/min)	TWR (g/min)
1	100	20	0.1	0.065	0.030
2	100	30	0.2	0.096	0.002
3	100	40	0.3	0.157	0.003
4	200	20	0.2	0.068	0.009
5	200	30	0.3	0.098	0.002
6	200	40	0.1	0.167	0.003
7	300	20	0.3	0.069	0.005
8	300	30	0.1	0.101	0.002
9	300	40	0.2	0.159	0.002

V. Effect of input parameters on MRR:

The signal to noise (S/N) ratio for MRR has been obtained using MINITAB 15 software and has been shown in fig 1.

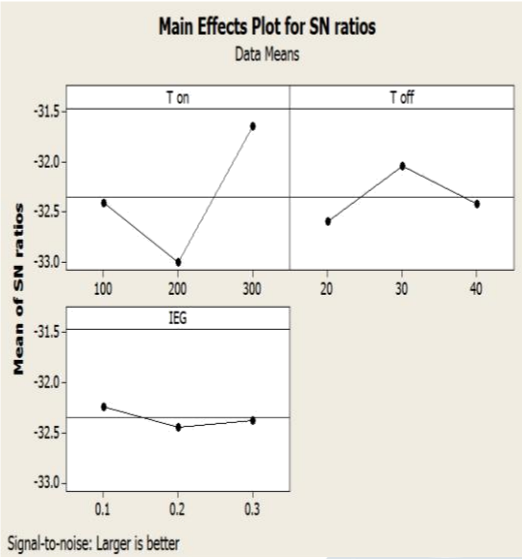

Fig 1. **S/N ratio graph for MRR**

From fig 1, it is clear that the MRR decreases up to certain point as the pulse on time increases, and then increases whereas there is a sharp increase and decrease of MRR in pulse off time and in IEG, respectively. The optimal values are A3-B2-C1, i.e. pulse on time 300 µs, pulse off time with 30µs and IEG with 0.1mm. The response table for MRR have been given in table 4, as this indicates the most significant parameter is pulse on time, followed by pulse off time and IEG. ANOVA has been carried out to indicate the significance of individual process parameters and this has been produced in table 5.

Table 4. **Response table for MRR**

Level	**Pulse on time (µs)**	**Pulse off time (µs)**	**IEG (mm)**
1	-32.41	-32.60	-32.23
2	-33.00	-32.04	-32.44
3	-31.65	-32.41	-32.38
Delta	1.35	0.56	0.21
Rank	1	2	3

Table 5. **Anova Table for MRR**

Parameters	**DoF**	**S of Sq**	**Adj MS**	**F value**	**P value**
Pulse on time (µs)	2	2.75	1.37	6.53	0.133
Pulse off time (µs)	2	0.49	0.24	1.14	0.467
IEG (mm)	2	0.07	0.033	0.16	0.861
Error	2	0.42	0.21	--	--
Total	8	3.72	--	--	--

VI. Effect of input parameters on TWR

The S/N ratio for TWR has been obtained and shown in fig 2, and it is clear that the TWR decreases up to certain point and then increases as the pulse on time increases, whereas again there is a sharp decrease of TWR in pulse off time and IEG. The optimal values are A2-B3-C3, i.e. pulse on time and pulse off time with 200µs and 40 µs, respectively and IEG with 0.3mm. The response table for TWR are given in table 6, as this indicates the most significant parameter is pulse on time and followed with pulse off time and IEG. ANOVA has been carried out to indicate the significance of individual process parameters that affects the TWR and this has been produced in table 7.

Table 6. Response table for TWR

Level	**Pulse on time (µs)**	**Pulse off time (µs)**	**IEG (mm)**
1	50.96	50.96	51.36
2	47.11	49.46	48.52
3	50.18	47.83	48.37
Delta	3.86	3.13	2.98
Rank	1	2	3

Table 7. **Anova Table for TWR**

Parameters	**DoF**	**S of Sq**	**Adj MS**	**F values**	**P Value**
Pulse on time (µs)	2	24.95	12.47	0.3	0.772
Pulse off time (µs)	2	14.75	7.37	0.17	0.851
IEG (mm)	2	16.95	8.47	0.2	0.833
Error	2	84.29	42.14	--	--
Total	8	140.93	--	--	--

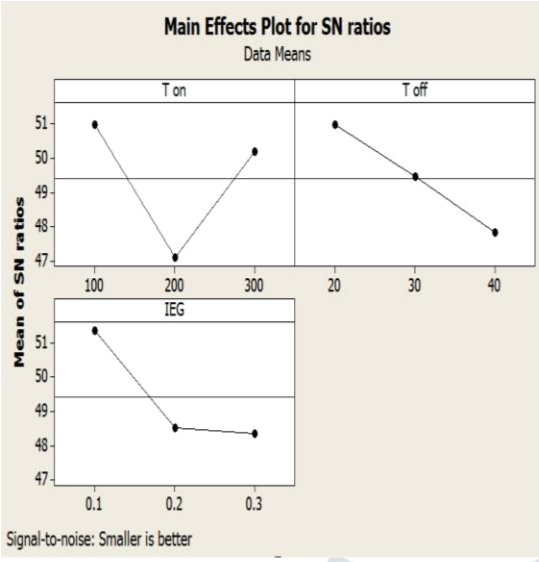

Fig 2**. S/N ratio graph for TWR**

VII. Conclusion

This article has presented an investigation on the optimization of machining parameters on the MRR and TWR in EDM. The significance of the parameters on MRR and TWR is determined by using ANOVA. Based on ANOVA, pulse on time have found to be significant parameter for best MRR and the same plays a significant role in the tool wear rate, also. With the increase in pulse on time, the MRR increases but it falls when the pulse off time increases. The similar case has been found with TWR also. The results were confirmed experimentally at 95% confidence interval. The future scope of this research work is to attempt with different dielectric materials with optimized process parameters.

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