STUDY OF EDM PARAMETERS FOR STAINLESS STEEL GRADE SUS420J2 BY GRAPHITE ELECTRODE USING TAGUCHI'S METHOD

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Abstract - Electrical Discharge Machining **(**EDM**)** has grown over the last few decades for manufacturing process**.** EDM process is very demanding so the optimum processing parameters are essential to increase the production rate and decrease the electrode wear ratio, which are processed by EDM and even the process is very costly**.** The material for machining is SUS420J2 stainless steel and graphite EDM-3 are considered to be an electrode**.** The machining factors used are current, voltage, on time and duty factor over the responses material removal rate **(**MRR**)**, electrode wear ratio **(**EWR**)** and surface roughness **(**Ra**).** Using Taguchi method, an L9 orthogonal array is used in the experiment and three levels corresponding to each of the variables are taken. The best solution of each parameter for MRR was determined as A3B3C2D3. The most factors which influence the material removal rate is current, on time, voltage, and duty factor respectively.The best of parameters for EWR was A1B1C3D2. The most factors which influence the electrode wear ratio is voltage, current, duty factor, and on time respectively.

Keywords - EDM, Graphite, Taguchi, Stainless, SUS420J2

I. INTRODUCTION

Nowadays, manufacturing industries are facing challenges from such difficulttocut materials. Stainless steel is outstanding to resist corrosion and staining, and low maintenance make it an ideal material for many applications where both the strength of steel and corrosion resistance are required. Stainless steel is one of difficult- to- cut materials. Graphite is widely used as electrode material in EDM, this is due to its low density and good electrical along with its machinability [1,2]. As a thermal erosion process, electrical discharge machining (EDM) is capable of machining all electrically conductive materials irrespective of their hardness. The temperature of the plasma (>10,000 K) during the discharging process is much higher than the melting point of all materials. Therefore, the EDM process offers to machine stainless steels. This paper presents performance of graphite (Poco EDM-3)[3-4]. The Taguchi method is a technique that provides an efficient methodology for process optimisation. It has been widely used for process optimisation. This is due to the advantages of the design of experiment using Taguchi's technique, which includes simplification of experimental plan and feasibility of study of interaction between different parameters. Shahul Backer et.al investigated the optimization of MRR and EWR on EDM by Using Taguchi's Method and ANOVA. The process parameters such as peak current, pulse on time and pulse off time were optimized with EDM for OHNS EN-31[5-6]. Rajmohan T. investigated the optimization of Machining Parameters in Electrical Discharge Machining (EDM) of 304 Stainless Steel[7-8]. The work are carried out as per design of experiment approach using L9 orthogonal array. The results are analyzed using ANOVA and response graphs. From this study, it is found that different combinations of EDM process parameters are required to achieve higher MRR for 304SS. Regardless of category of the performance characteristics, a greater S/N ratio value corresponds to a better performance. The optimal value of machining parameters is the level with the greatest S/N ratio value. Lesser number of experiments is required in this method. As a consequence, time as well as cost is reduced considerably. Taguchi proposes experimental plan in terms of orthogonal array that gives different combinations of parameters and their levels for each experiment. According to this technique, the entire parameter space is studied with minimal number of necessary experiments only [9-10]. Based on the average output value of the quality characteristic at each parameter level, main effect analysis is performed. Analysis of variance (ANOVA) is then used to determine which process parameter is statistically significant and the contribution of each process

II. DETAILS EXPERIMENTAL

2.1. Materials and Procedures

The experiments were conducted using Mitsubishi Electric Automation (EA8 - ADVANCE SERIES). The workpieceisSUS420J2 stainless steel and graphite EDM-3 from POCO Graphite, Inc. was used as an electrode. EDM-3 is an isotropic, ultrafine grain graphite. From the previous studies of Lee et al. [7], they used the Taguchi approach and found that the characteristics of an EDMed surface, such as surface roughness and white layer thickness are mainly influenced by current and discharge duration.

The Taguchi method can be designed according to the L9 Orthogonal Array. The values of the level 1 and level 3 were selected from the initial values and ends values of the preliminary experiment, values of level 2 is a linear interpolation of level 1 and level 3 were

presented in **Table 1**. The array consists of four control parameters and three levels, as shown in **Table2.**

Table1:Factors and levels

Factor	Level 1	Level 2	Level 3	Unit
Voltage	80	170	260	V
Current	5	25	40	A
On time	12	108	200	µs
Duty factor	33	54	75	%

Table 2: L9 Orthogonal Array

	A	B	C	D
No	**V**	**I**	**te**	**DF**
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

III. RESULTS AND DISCUSSION

3.1.Materialremovalrate(MRR)

The experiment was repeated twice (n=2) and Signal-Noise-Ratio(S/N) was calculated by equation (1).Largerthe better was used for determination of MRR.

$$S/N_L = -10\log\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right) \quad (1)$$

Apply the result of the experiment to analyse variance by using Minitab 18.0to provide the average Signal-Noise-Ratio (S/N) shown in**Fig.1**.

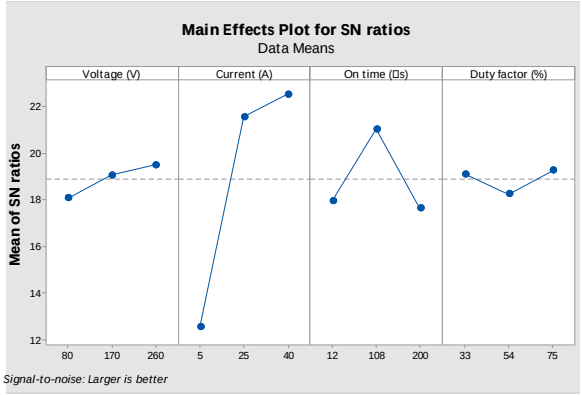


Fig.1. MaineffectsforSignal-Noise-Ratio(S/N)ratioon MRR.

Table 3 shows Signal to Noise Ratios that was obtained from Fig 1. The greater the absolute difference between maximum and minimum S/N ratio the significant the factor to MRR is, the difference is called delta.

Table3:Response for S/N Ratios on MRR

Level	Voltage (V)	Current (A)	On time (µs)	Dutyfactor (%)
1	18.07	12.55	17.96	19.11
2	19.06	21.55	21.04	18.25
3	19.50	22.52	17.63	19.27
Delta	1.44	9.97	3.41	1.01
Rank	3	1	2	4

Most significant factors are current shows the greatest delta of 9.97 followed by on time with delta of 3.41, delta value of voltage is 1.44 and delta of duty factor is 1.01. The greatest delta values will be ranked first follow by the lesser delta values. The ranks show the most significant factors to least significant factors which are current, on time, voltage and duty factor.

3.2. Electrode wear ratio(EWR)

The experimental design is shown in table 4.5. The experiment was repeated twice (n=2) and Signal-Noise-Ratio(S/N) was calculated by equation (2).Smaller the betterwas used for determination of EWR.Signal-Noise-Ratio (S/N) which shows in **Fig.2.**

$$S/N_S = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} y_i^2\right)$$

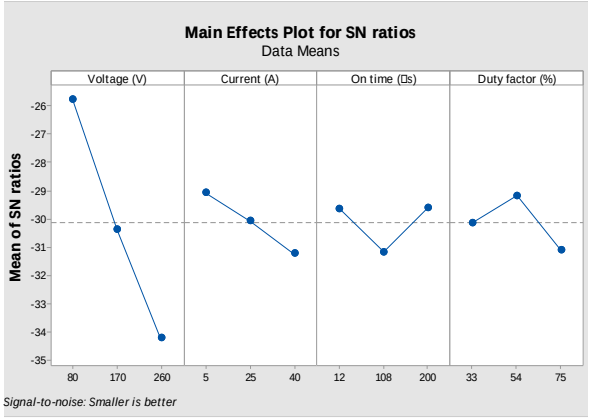


Fig.2 Main effects for Signal-Noise-Ratio (S/N) on EWR.

Table 4 shows Signal to Noise Ratios that was obtained from **Fig.2.**

Table 4 :Response for S/N Ratios on EWR

Level	Voltage (V)	Current (A)	On time (µs)	Dutyfactor (%)
1	-25.79	-29.08	-29.63	-30.12
2	-30.38	-30.08	-31.16	-29.18
3	-34.23	-31.23	-29.61	-31.09
Delta	8.44	2.15	1.55	1.91
Rank	1	2	4	3

The ranks show the most significant factors to least significant factors which are voltage, current, on time and duty factor, respectively.

3.3. Surface roughness(Ra)

Surface roughness normally shows quality of EDMed surface.Table5shows surfaceroughness of workpiece obtained from the experiments by Taguchi method.TheaverageSignal-Noise-Ratio(S/N) was showninFig.3.

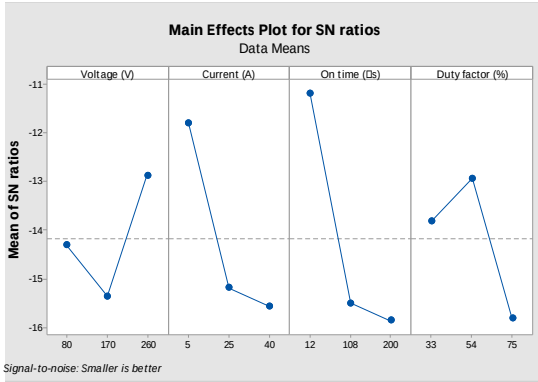


Fig.3. Main effects for Signal-Noise-Ratio (S/N) of each factor on Ra.

Table 5 :Response for S/N Ratios on Ra

Level	Voltage (V)	Current (A)	On time (µs)	Dutyfactor (%)
1	-14.31	-11.79	-11.19	-13.81
2	-15.37	-15.19	-15.50	-12.93
3	-12.87	-15.56	-15.86	-15.81
Delta	2.50	3.77	4.68	2.88
Rank	4	2	1	3

Table 5 shows Signal to Noise Ratios that was obtained from Fig.3.Most significant factors are voltage shows the greatest delta of on time is 4.68 followed by current with delta of 3.77, delta value of duty factor is 2.88 and delta of voltage is 2.50. The ranks show the most significant factors to least significant factors which are on time, current, duty factor and voltage, respectively.

3.4 Confirmation Test

The confirmation test for the best solution of each parameters with its levels were conducted to evaluate quality characteristics for EDM. Table 6 shows the comparison of the experimental results for the optimal conditions with predictedresults for optimal parameters for MRR, EWR and Ra.

Table6 :Result of confirmation experiments

Response value	Experiment from L9	Estimation from S/N	Difference
MRR			
Level	$A_3B_3C_2D_1$	$A_3B_3C_2D_3$	
MRR	19.014	23.077	4.063
S/N Ratio	25.547	27.263	1.716
EWR			
Level	$A_1B_1C_1D_1$	$A_1B_1C_3D_2$	
EWR	16.244	14.680	-1.564
S/N Ratio	-24.223	-23.336	0.887
Ra			
Level	$A_1B_1C_1D_1$	$A_3B_1C_1D_2$	
MRR	2.676	2.415	-0.261
S/N Ratio	-8.549	-7.657	0.892

The maximum experiment values of MRR is No.9 (L9) is $A_3B_3C_2D_1$ = 19.014 mm³/min while Main effects plot for S/N ratio is $A_3B_3C_2D_3$. So experiment for $A_3B_3C_2D_3$ was carried out and the result gave 23.077 mm³/min. It can be seen from this table that the difference between experimental result and the estimated result is 4.063 mm³/min, which shows a significant improvement.

The comparisons of the EWR according to estimation from S/N ratio is$A_1B_1C_3D_2$ that gave differences improving = -1.564 %.

Surface roughness is 2.415 µs with $A_3B_1C_1D_2$ from estimation. The comparison again shows the agreement between the predicted and the experimental is -0.261 µm.

The conditions experiment yield the optimal values that MRR, EWR, and Ra is shown to have the satisfying results. The influence of peak current for the best MRR is shown in **Fig.4**. These factors contribute to difference in temperature gradient of the workpiece which lead to difference in solidification causing surface roughness.**Fig.5** shows EDMed surface that obtained from the best conditions for surface roughness. It was looked clearly smoother than that of higher peak current.

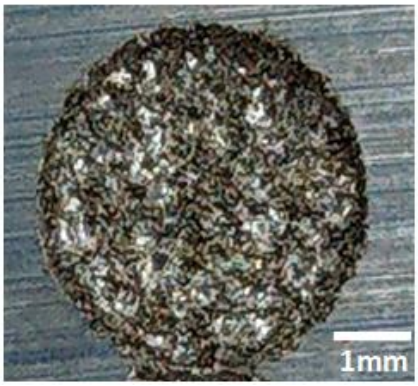


Fig.4. EDMed surface for considering for MRR.

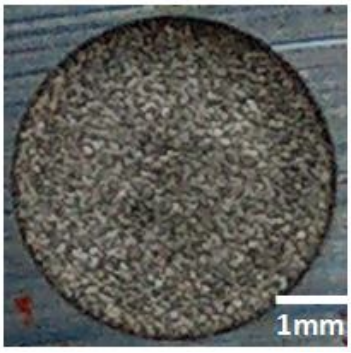


Fig.5. EDMed surface for considering for Ra.

CONCLUSIONS

In this study, EDM on Stainless Steel Grade SUS420J2 by a graphite electrode using Taguchi's method is proposed. Results were summarized as follows:

1. The best solution of each parameter for MRR was determined as A3B3C2D3. Voltage 260 V at level 3, current at 40 A at level 3, on time at 108 μs at level 2, and duty factor at 75 % at level 3. The most factors which influence the material removal rate is current, on time, voltage, and duty factor respectively.

2. The best solution of each parameter for EWR was determined as A1B1C3D2. Voltage 80 V, current 5 A, on time at 200 μs, and duty factor at 54 %. The most factors which influence the electrode wear ratio is voltage, current, duty factor, and on time respectively.

3. The best solution of each parameter for surface roughness was determined as A3B1C1D2. Voltage 260 V, current at 5 A, on time at 12 μs, and duty factor at 54 %. The most factors which influence the surface roughness is on time, current, duty factor, and, voltage respectively.

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