Influence of Process Parameters on Surface Quality, TWR and MRR in Electro Discharge Machining of Inconel 825 Material

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Abstract--- Electrical discharge machining (EDM) is a well-established machining option for manufacturing geometrically complex or hard material parts that are extremely difficult-to-machine by conventional machining processes. However,due to the process nature, there is still incomprehension onprocess parameters influence at the final quality features, endingup by lower productivity and quality ratios. In this research taguchi Methodology is used to investigate the effect various Process Parameters like pulse on time, pulse off time, peak current and voltage on inconel 825. Present study attempts to optimize the complex electrical discharge machining (EDM) process (like: Material removal rate (MRR), Tool wear rate (TWR), Surface Roughness,(Ra) using taguchi Methodology. The analysis is checked by Anlysis of variance with 95% Significant level.

I. INTRODUCTION

EDM have explored a number of ways to improve the sparking efficiency including some unique experimental concepts that depart from the EDM traditional sparking phenomenon. 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 [1]. Norliana Mohd Abbas et. al. [2] (2007) review that Electrical discharge machining (EDM) is one of the earliest non-traditional machining processes. EDM process is based on thermoelectric energy between the work piece and an electrode. A pulse discharge occurs in a small gap between the work piece and the electrode and removes the unwanted material from the parent metal through melting and vaporizing. The electrode and the work piece must have electrical conductivity in order to generate the spark. There are various types of products which can be produced using EDM such as dies and moulds. Parts of aerospace, automotive industry and surgical components can be finished by EDM. Jose Duarte Marafona et. al. [3] (2009) show the influence of the hardness of the alloy steel on the material removal rate and on the workpiece surface roughness. The Taguchi methodology was used to study that influence. The result of the verification test for workpiece surface roughness was a strong confirmation. This type of outcome allows the use of the additive model to predict the workpiece surface roughness with an average error of 0.4 %.

II. MATERIALS AND METHODOLOGY

Inconel825alloy was used for the present investigation.Inconel825 is a high performance alloys, mainly Nickel Alloy and also Cobalt and Titanium. Inconel 825 might be used in any environment that requires resistance to heat and corrosion. They have good resistance to oxidation and corrosion at high temperatures. Inconel825 typically finds application in Furnace components, chemical processing, Food processing industry and nuclear engineering [4]. In recent past Inconel825 super alloy gained dominance in aerospace applications because of its special features. This alloy does work-harden during machining and has higher strength and "gumminess" not typical of steelsThe Chemical Composition of Inconel 825 is describe below.

	C	Si	Mn	S	P	Cr	Fe
% Cont	0.026	0.074	0.12	0.005	0.01	19.65	28.62
	V	Al	Ti	Ni	Mo	Co	Cu
% Cont	0.021	0.094	0.677	38.575	3.096	0.584	1.789

Table. 1: Chemical Composition of Inconol 825

Fig. 1: Workpiece Material after EDM

Two major tools used in Taguchi's method are one is signal(S) to noise (N) ratio i.e. S/N ratio to measure the quality and the other is orthogonal arrays to accommodate many factors simultaneously to evaluate the machining performances. The ability of orthogonal arrays lies in evaluating the machining performance with a less number of experiments when compared to full factorial experiments which reduces the number of trials [5]. This greatly reduces the time required in conducting the experiments and also in evaluating the significant and insignificant parameters.

III. EXPERIMENTAL SET UP

The experiments were carried out on JOEMARS Z 50 JM-322 EDM machine. The responses studied are MRR, TWR and Surface roughness. The Parameters studied are Pulse on time, Pulse off Time, Current, Voltage. The die electric medium is DEF-92. Every experiment is carried out for constant 20 minutes.

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Sr no	Current (amp)	Pulse on time (µm)	Pulse off time (µm)	Voltage (V)	MRR (mm^3/min)	TWR (mm^3/min)	SR (µs)
1	9	50	40	10	4.15909091	2.926786	11.446
2	9	60	50	12	4.41154791	3.160714	14.43
3	9	70	60	14	4.45945946	3.721429	12.909
4	9	80	70	16	3.86977887	3.324405	8.837
5	13	50	50	14	3.6019656	1.778571	11.612
6	13	60	40	16	6.27334152	3.114881	12.894
7	13	70	70	10	6.28931204	3.541667	15.557
8	13	80	60	12	9.35687961	4.942857	10.996
9	17	50	60	16	2.71683047	1.211905	12.601
10	17	60	70	14	3.64066339	1.453571	14.211
11	17	70	40	12	10.6234644	3.402381	12.359
12	17	80	50	10	10.6996314	3.697619	15.203
13	21	50	70	12	3.70515971	1.166667	12.084
14	21	60	60	10	4.57248157	1.2	17.144
15	21	70	50	16	9.38206388	2.447024	16.95
16	21	80	40	14	13.2487715	3.815476	11.446

Table. 2: Observed Values for Performance Characteristics

A. Material Removal Rate:

The material MRR is expressed as the ratio of the difference of weight of the workpiece before and after machining to the machining time and density of the material [6].

$$MRR = \frac{(W_{tb} - W_{ta})}{D \times t} \quad (3.1)$$

Where,

W_{tb}=weight before machining in gm.
W_{ta}=weight after machining in gm.
D=density of work piece material in gm/mm^3.
t=time consumed for machining in minute.

The weight of the work piece and tool is measured on precise weighing machine having least count of 0.0001 gm.

B. Tool wear ratio:

During the EDM process considerable amount of the material from the tool is removed. However the amount of the material removed from the tool is less than that of the work piece. TWR is expressed as the volumetric loss of tool per unit time, expressed as [7]

$$TWR = \frac{(W_{tb} - W_{ta})}{D \times t} \quad (3.2)$$

IV. Result and Discussions

S/N Ratio, Mean plot and ANOVA for MRR

Level	Ip	Ton	Toff	V
1	12.50	10.89	17.82	15.54
2	15.62	13.32	16.01	16.05
3	15.25	17.23	13.57	14.45
4	16.62	18.55	12.58	13.96
Delta	4.11	7.66	5.24	2.10
Rank	3	1	2	4

Table. 3: Response Table for Signal to Noise Ratios of MRR

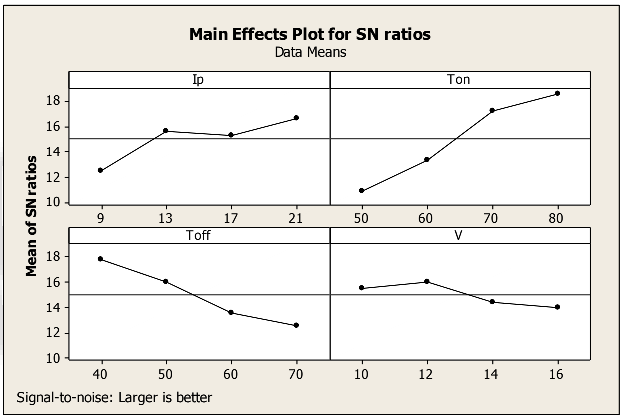

Fig. 2: Main Effect Plot for S/N Ratio of MRR (Larger is Better)

level	Ip	Ton	Toff	V
1	4.225	3.546	8.576	6.430
2	6.380	4.725	7.024	7.024
3	6.920	7.689	5.276	6.238
4	7.727	9.294	4.376	5.561
Delta	3.502	5.748	4.200	1.464
Rank	3	1	2	4

Table. 4: Response Table for Means of MRR-brass

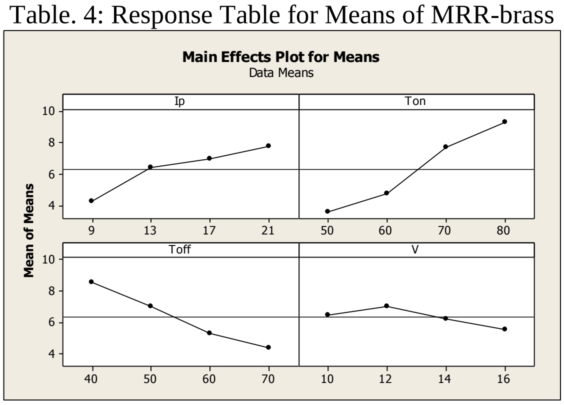

Fig. 3: Main Effect Plot for Means of MRR (Larger is Better)

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Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
Ip	3	26.931	26.931	8.977	10.41	0.043	16.88
Ton	3	83.832	83.832	27.944	32.41	0.009	52.55
T off	3	41.811	41.811	13.937	16.16	0.023	26.20
V	3	4.366	4.366	1.455	1.69	0.339	2.73
Error	3	2.587	2.587	0.862			1.62
Total	15	159.528					
S = 0.928621 R-Sq = 98.38% R-Sq(adj) = 91.89%							

Table. 5: Analysis of variance for MRR (Brass as electrode)-brass

- The significant parameters can be easily identified and rank the parameter as per the response table for S/N Ratio and means.
- The most significant parameters for MRR are Pulse on time and Pulse off Time.
- The optimum condition for maximum MRR is I_p (21 amp), T_{on} (80 µs), T_{off} (40 µs), V (12 Volt).
- The Analysis of Variance table can also justify the rank order of significant parameter as Ton (52.55%), Toff (26.20%), Ip (16.88%), V (2.73%).
- Percentage contribution of residual error is 1.62 %. It strengthens the analysis as it is on minimum side. Maximum percentage contribution is of Pulse on time 52.55 %.

S/N Ratio, Mean plot and ANOVA for TWR

level	Ip	Ton	Toff	V
1	-10.293	-4.334	-10.366	-8.314
2	-9.933	-6.174	-8.532	-8.962
3	-6.728	-10.202	-7.137	-7.824
4	-5.582	-11.826	-6.502	-7.436
Delta	4.711	7.491	3.864	1.526
Rank	2	1	3	4

Table. 6: Response Table for Signal to Noise Ratios of TWR (Smaller is better)-brass

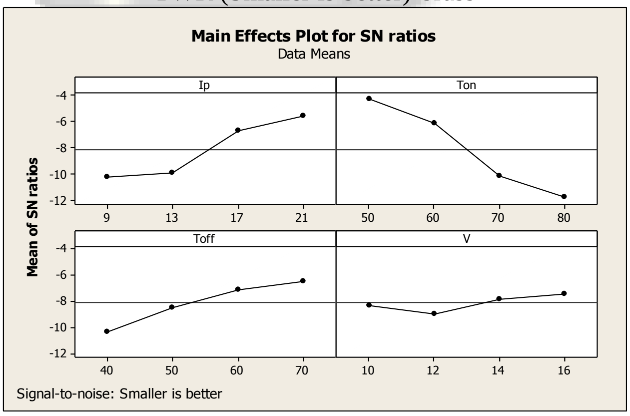

Fig. 4: Main Effect Plot for S/N Ratio of TWR (Smaller is Better)

level	Ip	Ton	Toff	V
1	3.283	1.771	3.315	2.842
2	3.344	2.332	2.771	3.168
3	2.441	3.278	2.769	2.692
4	2.157	3.945	2.372	2.525
Delta	1.187	2.174	0.943	0.644
rank	2	1	3	4

Table. 7: Response Table for Means of TWR (Smaller is better)-brass

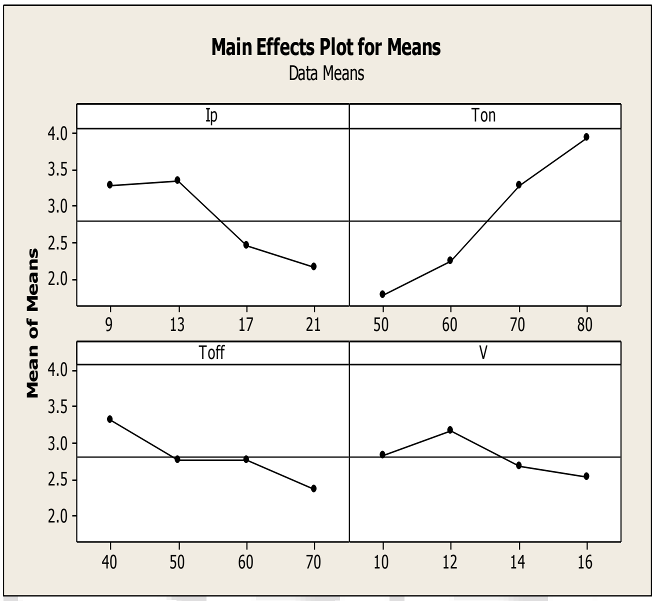

Fig. 5: Main Effect Plot for Means of TWR (Smaller is Better)

- The significant parameters can be easily identified and rank the parameter as per the response table for S/N Ratio and means of TWR Considering Brass as tool.
- The most significant parameters for TWR are Pulse on time and Current.
- The optimum condition for minimum TWR is I_p (21 amp), T_{on} (50 µs), T_{off} (70 µs), V (16 Volt).
- An analysis of Variance table 5.22 shows the significance parameter effect on TWR. The Analysis of Variance table can also justify the rank order of significant parameter as Ton (60.09%), Ip (22.04%), Toff (9.26%), V (4.62%).
- Percentage contribution of residual error is 3.97%. It strengthens the analysis as it is on minimum side. Maximum percentage contribution is of Pulse on time 60.09 %.

S/N Ratio, Mean plot and ANOVA for SR:

level	Ip	Ton	Toff	V
1	-21.38	-21.53	-22.18	-23.33
2	-22.04	-23.28	-23.18	-21.87
3	-22.63	-23.12	-22.43	-22.52
4	-23.60	-21.72	-21.87	-21.93
Delta	2.23	1.75	1.31	1.46
Rank	1	2	4	3

Table. 8: Response Table for Signal to Noise Ratios of SR (Smaller is better)-brass

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Source	Df	Seq ss	Adj ss	Adj ms	F	P	% Contribution
Ip	3	4.2864	4.2864	1.4288	5.55	0.096	22.04
Ton	3	11.6833	11.6833	3.8944	15.14	0.026	60.09
Toff	3	1.8011	1.8011	0.6004	2.33	0.252	9.26
V	3	0.8983	0.8983	0.2994	1.16	0.452	4.62
Error	3	0.7719	0.7719	0.2573			3.97
Total	15	19.4410					

Table. 9: Analysis of Variance for TWR, using Adjusted SS for Tests-brass

Level	Ip	Ton	Toff	V
1	11.91	11.94	12.92	14.84
2	12.76	14.67	14.55	12.47
3	13.59	14.44	13.41	13.43
4	15.29	12.50	12.67	12.82
Delta	3.38	2.73	1.88	2.37
Rank	1	2	4	3

Table. 10: Response Table for Means of TWR (Smaller is Better)-brass

- The most significant parameter for SR is Current.
- The optimum condition for minimum SR is I_p (9 amp), T_{on} (50 µs), T_{off} (70 µs), V (12 Volt).
- An analysis of Variance table 5.25 shows the significance parameter effect on Surface roughness. The significant parameters can be easily identified and rank the parameter as per the response table.
- The Analysis of Variance table can also justify the rank order of significant parameter as Ip (32.71%), Ton (29.62%), V (17.15%), Toff (10.91%).

Source	Df	Seq.ss	Adj ss	Adj ms	F	p	% Contribution
Ip	3	24.958	24.958	8.319	3.41	0.170	32.71
Ton	3	22.601	22.601	7.534	3.09	0.190	29.62
Toff	3	8.323	8.323	2.774	1.14	0.459	10.91
V	3	13.090	13.090	4.363	1.79	0.322	17.15
Error	3	7.316	7.316	2.439			9.64
Total	15	76.287					

Table. 11: Analysis of Variance for Ra, using Adjusted SS for Tests-brass

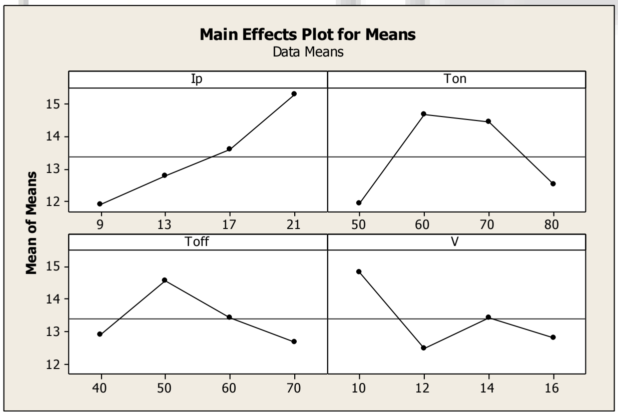

Fig. 6: Main Effect Plot for Means of SR (Smaller is Better)

V. CONCLUSION

In this work the effect of various process parameters like Pulse on time, Pulse off time, Current and Voltage on responses like MRR, TWR and SR have studied. The Taguchi methodology is applied for investigation and following conclusion are drawn.

- The most significant parameter for MRR is Pulse on time with 52.55% because of its dominant effect on total energy.
- For TWR the most significant parameter are Pulse on time and Current with 60.09% and 22.04% respectively.
- Current is most significant for SR.
- We also understood from above study that Pulse on time and pulse off time combination is important.

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