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Investigation of Machine-ability of Inconel 800 in EDM with Coated Electrode

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Abstract. The Inconel 800 is a high temperature application alloy which is classified as a nickel based super alloy. It has wide scope in aerospace engineering, gas Turbine etc. The machine-ability studies were found limited on this material. Hence This research focuses on machine-ability studies on EDM of Inconel 800 with Silver Coated Electrolyte Copper Electrode. The purpose of coating on electrode is to reduce tool wear. The factors pulse on Time, Pulse off Time and Peck Current were considered to observe the responses of surface roughness, material removal rate, tool wear rate. Taguchi Full Factorial Design is employed for Design the experiment. Some specific findings were reported and the percentage of contribution of each parameter was furnished

1. Introduction

Based on the review it was found that, some research works were reported on EDM in machining performance improvements on such difficult-to-cut materials. Kuppan et al[1] investigation was on EDM deep hole drilling on Inconel 718. The process variables like peak current, pulse on-time, duty factor and electrode speed were considered for their investigation as factors. In which the authors developed mathematical models for the responses of MRR and depth averaged surface roughness (DASR) and used response surface methodology. Rajyalakshmi and Venkata Ramaia [2], investigations were for the performance measures like MRR, SF, and SG in Wire EDM on Inconel 825 material they used Taguchi grey relational analysis for optimizing process parameters. MuthuKumar et al[3] investigation was in WEDM process to optimize parameters by Gray–Taguchi Method for machining Incoloy800 super alloy with multiple performance characteristics such as MRR, surface roughness and Kerf. Lin et al[4] analyzed parameter optimization on micro milling EDM for the machining of Inconel 718. The another attempt was made by Muthu Kumar et al [5] on WEDM process to optimize parameters for improving responses of MRR, SR and Ker width for machining Titanium alloy. The authors recently developed a Mathematical Model for Radial Overcut on Electrical Discharge Machining for Incoloy 800. And they used Response Surface Methodology[6]. Rathi and Mane[7] studied the Effect of Powder Mixed dielectric in EDM of Inconel 718 machining with powders like Silicon carbide, Aluminum oxide, Graphite. Karunakaran and Chandrasekaran[8] work was on nPMEDM to study the influence of Al, Si and MWCNTs nonopowders. This work analyse the machine-ability performance on Inconel 800 with Silver coated electrolyte copper Electrode as well as plain electrode[9].

2. Experimentation

The factors peak current varied at three levels as 5a, 10A and 15A, similarly the pulse on time and Pulse off times were considered at three levels as 6μs, 7μs , 8μs and 3 μs, 4 μs, 5μs respectively. Taguchi Full factorial Design is shown in table 1. The MINITAB release 16 software was used for obtaining such design. The gap voltage 240V is maintained. In this experiment, the work piece (ϕ22×20mm) was Inconel 800. Additionally, the tool material (ϕ25×23mm) was Silver Coated electrolytic copper. The Coating Thickness is neglected. Polarity used was straight. The observations like SR, MRR and TWR were recorded in table 2. The average of three trails was considered for recording to avoid observational error. The machining time per run is 5 minutes. The MRR and TWR are computed by using the equation (1) and (2). The Electronica Machine Tools make Xpert 1model die sinking type CNC EDM machine was employed in this research. Kerosene is dielectric fluid in this machine because of its property of very low viscosity and it gets flushed away easily. The Taylor Hobson make, Surtronic3+ branded contact type profile-meter was used to measure surface roughness with 0.8mm cut of length. MRR is mathematically expressed equation 1, where Wj1 and Wj2 are weights of the job/ Sample before and after the machining respectively. The machining time is t minutes.

Table 1 Taguchi Full Factorial Design

Experimental. Run	*Current (A)*	*Pulse On Time (μs)*	*Pulse Off Time (μs)*
1	5	6	3
2	5	6	4
3	5	6	5
4	10	6	3
5	10	6	4
6	10	6	5
7	15	6	3
8	15	6	4
9	15	6	5
10	5	7	3
11	5	7	4
12	5	7	5
13	10	7	3
14	10	7	4
15	10	7	5
16	15	7	3
17	15	7	4
18	15	7	5
19	5	8	3
20	5	8	4
21	5	8	5
22	10	8	3
23	10	8	4
24	10	8	5
25	15	8	3
26	15	8	4
27	15	8	5

Table 2 Experimental Results

Experimental. Run	***MRR (g/min)***	***TWR (g/min)***	***SR (µm)***
1	0.07148	0.00042	1.34
2	0.09725	0.00059	1.37
3	0.10321	0.00068	1.67
4	0.15427	0.00085	1.4
5	0.1763	0.00114	1.51
6	0.20078	0.00127	1.71
7	0.22187	0.00158	1.43
8	0.2665	0.00256	1.55
9	0.31891	0.00147	1.82
10	0.23619	0.00166	1.43
11	0.27624	0.00171	1.65
12	0.29222	0.00197	1.93
13	0.31491	0.00225	1.45
14	0.33568	0.00277	1.73
15	0.37154	0.00294	2.05
16	0.4653	0.00379	1.55
17	0.50848	0.00415	1.86
18	0.53285	0.00272	2.28
19	0.36433	0.00384	1.58
20	0.41234	0.00407	1.91
21	0.45822	0.0045	2.24
22	0.48716	0.00483	1.63
23	0.52833	0.0056	2.03
24	0.57562	0.00583	2.41
25	0.59838	0.00654	1.92
26	0.67215	0.00668	2.07
27	0.74133	0.00702	2.58

MRR = (Wj1 –Wj2) / t (1)
TWR is expressed mathematically in equation 2.
TWR= (Wt1 - Wt2) /t (2)
Where Wt1 and Wt2 are weights of the job/ sample before and after the machining respectively.

3. Results and Discussion

A. The Material Removal Rate (MRR)

The results were graphically analyzed and depicted the machinabilty characteristics. The MRR performances when maintained the constant Pulse on Times of 6 µs, 7 µs and 8 µs are depicted in figure 1 to figure 3.

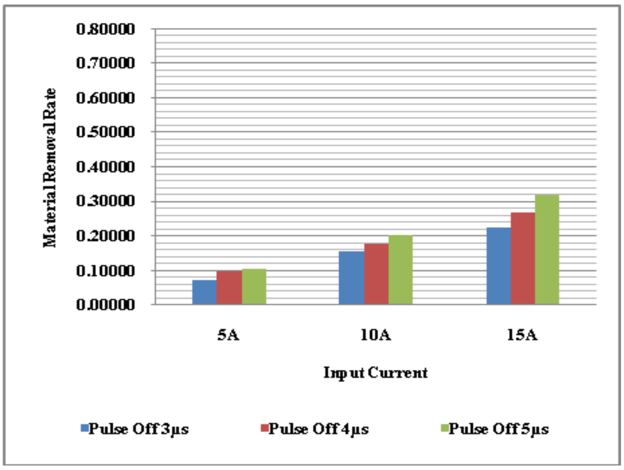

Figure 1. MRR at Pulse on Time 6 µs

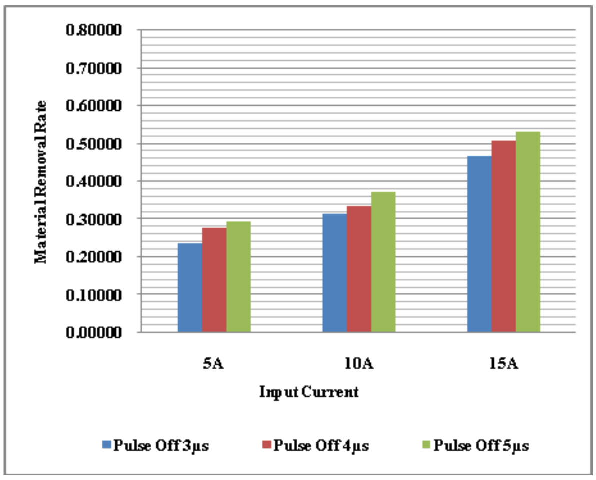

Figure 2. MRR at Pulse on Time 7 µs

The results show that the MRR linearly increases with increase of peak Current. The MRR with respect to pulse off time is also significant. The parameters influence with respect to maximum MRR were numerically estimated and tabulated in the Table 3. The Pulse on Time increment also increases the MRR. Hence controlling all three parameters will help to get desired machine-ability quality for meeting the job requirements.

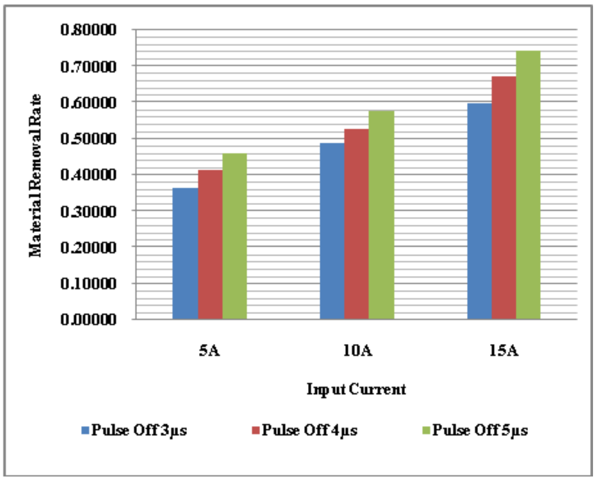

Figure 3. MRR at Pulse on Time 8 µs

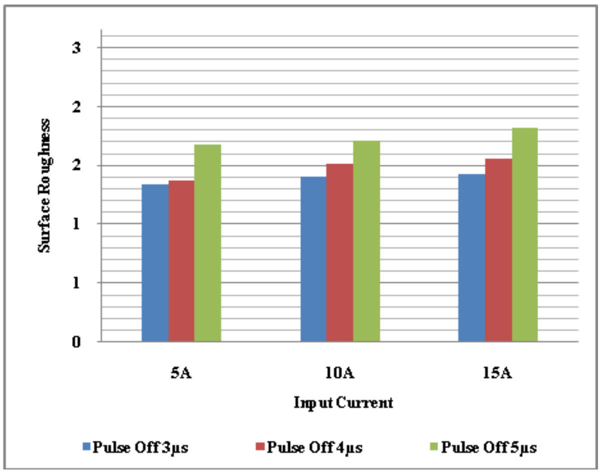

Figure 4. SR at Pulse on Time 6 µs

The Surface Roughness (SR)

The surface roughness on machined is a measure of surface finish.

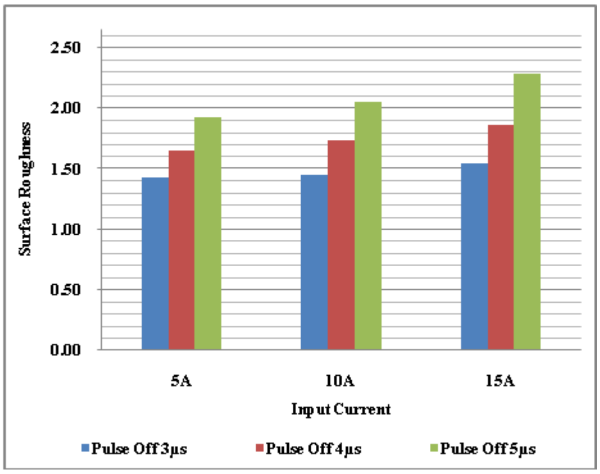

Figure 5. SR at Pulse on Time 7 µs

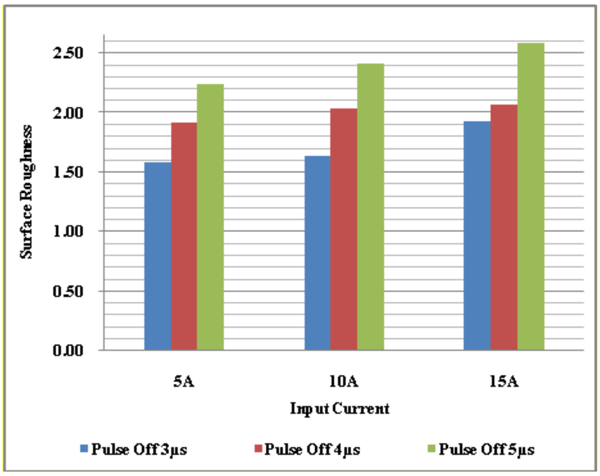

Figure 6. SR at Pulse on Time 8 µs

The SR performances when maintained the constant Pulse on Times of 6 µs, 7 µs and 8 µs are depicted in Figure 4 to Figure 6 respectively. The good surface quality usually obtained at minimum settings of operating parameters. But their individual contribution was analyzed with respect to maximum tool wear. The results were furnished in Table 4.

3. Tool Wear Rate (TWR)

The TWR was monitored and graphically depicted in Figure 7 to Figure 8 for the constant pulse on Time 6 µs, 7 µs and 8 µs respectively. TWR observed were minimum values at low pulse on Time, low pulse off time and low Peak Current settings. The TWR is comparatively lower than MRR. The TWR gradually increases with increase of the operating parameters values. Apart from general studies on Tool Wear behavior the in particular study also done. The contribution of each operating parameter with respect to maximum value of TWR was analyzed and furnished in Table 4.

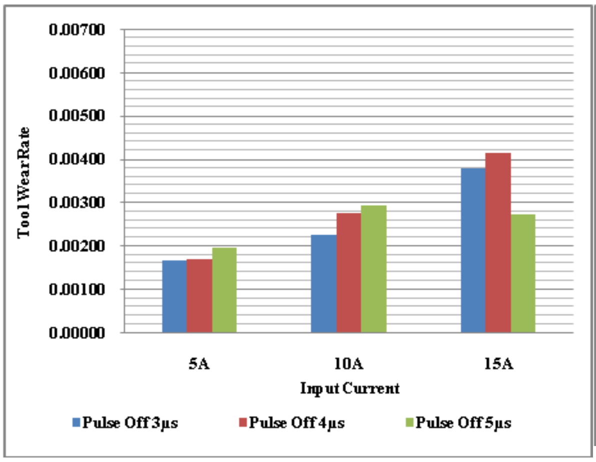

Figure 8. TWR at Pulse on Time 7µs

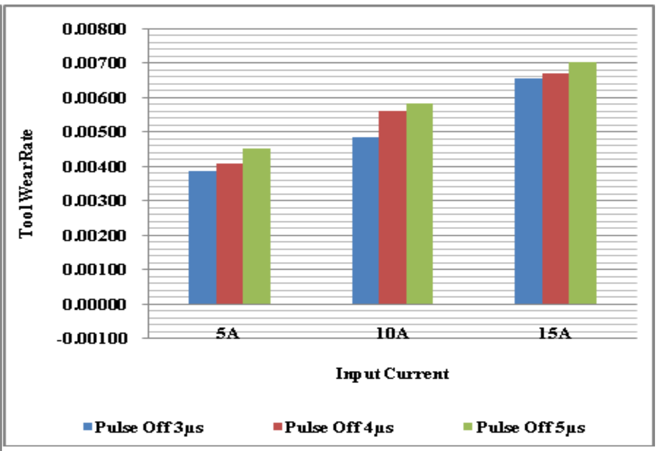

Figure 9. TWR at Pulse on Time 8 µs

Table 4. Contribution of Process Parameters

Experimental. Run	*MRR g/min*	*TWR g/min*	*SR (µm)*
1	9.60%	6.00%	51.90%
2	13.10%	8.40%	53.10%
3	13.90%	9.70%	64.70%
4	20.80%	12.10%	54.20%
5	23.80%	16.20%	58.50%
6	27.10%	18.10%	66.30%
7	29.90%	22.50%	55.30%
8	35.90%	36.50%	60.10%
9	43.00%	20.90%	70.50%
10	31.90%	23.70%	55.40%
11	37.30%	24.30%	64.00%
12	39.40%	28.00%	74.80%
13	42.50%	32.00%	56.20%
14	45.30%	39.40%	67.10%
15	50.10%	41.90%	79.50%
16	62.80%	54.00%	59.90%
17	68.60%	59.10%	72.10%
18	71.90%	38.70%	88.40%
19	49.10%	54.70%	61.10%
20	55.60%	57.90%	74.00%
21	61.80%	64.10%	86.80%
22	65.70%	68.80%	63.20%
23	71.30%	79.80%	78.60%
24	77.60%	83.00%	93.40%
25	80.70%	93.20%	74.50%
26	90.70%	95.20%	80.20%
27	100.00%	100.00%	100.00%

4. Conclusion

The machine-ability study on Inconel 800 is successfully carried out in EDM. The results are analyzed graphically. The Taguchi full factorial Design gives detailed results for this study. In this study the maximum MRR at higher setting was achieved as 0.74133 g/min. The SR obtained in the range of 1.34 µm to 2.58 µm. The tool wear was in the range on of 0.004 g/min to 0.007 g/min. The wear ratio (WR) is expressed as the ratio between TWR and MRR. The minimum of this ratio (0.0046) is economy which was obtained for the setting of 15A of Peak Current, Pulse on Time 6 µs and Pulse off Time 5µs and the yielded results are 0.31891g/min of MRR, 0.00147g/min of TWR and 1.82µm SR.

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