INVESTIGATION OF INFLUENCE OF SOME PROCESS PARAMETERS IN EDM OF INCONEL-800 WITH SIVER COATED ELECTRODE

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ABSTRACT

The Electrical discharge machining (EDM) is a sophisticated manufacturing process. It is preferable to produce multifaceted geometry with high accuracy in hard materials like Inconel 800 nickel based super alloy are tremendously difficult to machine by using conventional manufacturing processes. It is sometimes, only an alternative for generating accurate 3D complex shapes of macro, micro and nano features in such materials with the features of erstwhile advanced manufacturing processes. Such challenging task can be achieved by use of EDM is depending upon selection of appropriate process parameters. Taguchi full factorial Design based experimental investigation performed in this research aims to study the influence of input parameters in EDM on Inconel 800 with silver coated electrolytic copper electrode. The full factorial design is obtained from Minitab release 14 software. The experimental runs were performed with variable input conditions such as pulse off time, peak current and pulse on time to process Inconel 800 nickel based super alloy for analysing the response of surface roughness, material removal rate, and tool wear rate. The result of these experimental runs has helped to meet the manufacture requirements of preparing process parameter selection card for processing Inconel-800 jobs.

Keywords: EDM, silver coated electrode, surface roughness, tool wear rate, material removal rate.

INTRODUCTION

Konig, Klocke and Lenzen [1] highlighted that the innovations of new materials, the precision requirements are the causes for searching alternate manufacturing processes. Nowadays the high-speed milling and EDM preferred such challenging tasks [2]. In general most hard materials like high-strength aluminium alloys, nickel based super alloys, copper-based alloys etc are required to machine accurately with most complicated geometric features in accurately to be machined to meet the applications such as are in the fields of high temperature and high pressure applications, tool and die etc. In this circumstance the suitable single manufacturing process which can perform such a precise machining is EDM. The electrical conductivity of electrode is main cause for the precision of EDM on work piece. So here the conventional electrolyte copper electrode is coated with silver which already experimented that such coated electrodes increase the electrical conductivity by 26.8% and hence the MRR has increased and 25% of TWR has decreased considerably [3]. And also the pure kerosene dielectric medium enriched with SERVOTHERM oil in 10% of volume ratio to improve the machining performance. The Inconal 800 applicationa can be found in high pressure and High temperature field like nuclear reactors, electric power generation equipments, gas turbines, high temperature chemical vessels and etc. [4]. It is hard material, has high thermal strength but also has more tendencies for forming built–up edge and welding with tool [5]. Hence EDM is preferred to machine Inconel 800. The earlier investigations on Inconel materials are: MuthuKumar *et al*. [6] investigation was on WEDM process in Incoloy 800. They developed later a mathematical modelling for radial over cut on EDM of Incony 800[7]. LIN *et al*. [8] investigated on micro milling EDM of Inconel 718. Kuppan *et al*. [9] studied the influence of process parameters in EDM of deep hole drilling on Inconel 718. Rajyalakshmi and Venkata Ramaiah [10] studied parameters influence when EDM on Inconel 825 and Mahendra *et al*. [11] investigation was on Powder Mixed Electrical Discharge Machining (PMEDM) of Inconel 718. In the case of copper electrode Syed and Kuppan[12] used for investigation on PMEDM of W300 Die Steel similarly in PMEDM for H13 Steel by Gurtej *et al*. [13], for AISI D3 die steel by Jamadar and kavade [14], for AISI H -11 material by Mir *et al*. [15], for AISI 1045 steel by Shivam Goyal and Rakesh Kumar[16], for D2 Die steel by Gurule and Nandurkar [17], for EN 8 steel by Nimo et al[18], for Stavax material by Razak [19] and for EN 31 Steel by Soumyakant Padhee [20]. Here the investigation is influence of Silver Coated Electrolyte copper Electrode and servotherm enriched kerosene based dielectric fluid and process parameters in die sinking EDM of Inconel 800.

EXPERIMENTATION

The experimentations were designed as per Taguchi full factorial design. The same was used for recording observations. There were considered three input parameters as variable. Each variable is varying at three levels. The work piece of size ϕ22×20mm Inconel-800 is

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Table-1. Fixed factors and their description.

Working parameter	Description
Work piece	Inconel 800
Tool	Silver coated Electrolytic copper
Dielectric medium	kerosene + Servotherm EDM oil
Supply voltage	240 (V)
Polarity	Straight

The complete experimental observations were divided into three major set for explaining the experimental procedure. The Pulse off Times value has been maintained at 3 µs, 4 µs and 5 µs, as constant parameters in Set 1, Set 2 and Set 3 respectively. The other parameters (factors) like Pulse on time and Peak current were varied in each set

Table-2. The variable factors and their levels.

Input parameters	Level 1	Level 2	Level 3
Peak Current	5A	10A	15A
Pulse On Time	6µs	7µs	8µs
Pulse Off Time	3µs	4µs	5µs

Table-3. Experimental observation at pulse off time 3µs.

Run	Current (A)	Pulse on (µs)	Pulse off (µs)	MRR (g/min)	TWR (g/min)	SR (µm)
1	5	6	3	0.04862	0.00035	1.13
2	5	7	3	0.09418	0.00054	1.22
3	5	8	3	0.14722	0.00115	1.26
4	10	6	3	0.19576	0.00155	1.29
5	10	7	3	0.24813	0.00225	1.36
6	10	8	3	0.31480	0.00311	1.41
7	15	6	3	0.38793	0.00376	1.46
8	15	7	3	0.46530	0.00497	1.53
9	15	8	3	0.50149	0.00654	1.67

Table-4. Experimental observation at pulse off time 4µs.

Run	Current (A)	Pulse on (µs)	Pulse off (µs)	MRR (g/min)	TWR (g/min)	SR (µm)
10	5	6	4	0.05655	0.00039	1.17
11	5	7	4	0.10348	0.00060	1.26
12	5	8	4	0.17603	0.00129	1.29
13	10	6	4	0.22548	0.00165	1.36
14	10	7	4	0.29686	0.00250	1.47
15	10	8	4	0.37562	0.00382	1.53
16	15	6	4	0.43584	0.00398	1.57
17	15	7	4	0.50848	0.00510	1.68
18	15	8	4	0.57670	0.00668	1.72

employed. Additionally, the tool material (ϕ25×23mm) was silver coated electrolytic copper the experiments have been performed on Electronica Machine Tools make Xpert1 model die sinking type CNC EDM machine. The Taylor Hobson makes, Surtronic3+ branded contact type profile-meter was employed in surface roughness measurement with 0.8mm cut length and sampling number is three. The laboratory balance of semi micro with an accuracy of 0.00001g was employed in measuring weight loss tool and work material in before and after every run to compute MRR and TWR. Here pulse off time, peak current and Pulse on time values have been varied, to analyze the responses of MRR, SR and TWR with servotherm oil enriched Kerosene as Dielectric fluid and

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also with silver coated electrolytic copper as tool for machining 5 minutes for each experimental run. The fixed factor and their brief descriptions and the variable factors with their levels are furnished in Table-1 and Table-2 respectively.

Table-5. Experimental Observation at pulse off time 5μs.

Run	**Current** (A)	**Pulse on** (μs)	**Pulse off** (μs)	**MRR** (g/min)	**TWR** (g/min)	**SR** (μm)
19	5	6	5	0.06550	0.00047	1.24
20	5	7	5	0.11978	0.00068	1.33
21	5	8	5	0.19754	0.00141	1.41
22	10	6	5	0.28345	0.00182	1.47
23	10	7	5	0.32613	0.00277	1.58
24	10	8	5	0.40768	0.00439	1.67
25	15	6	5	0.46086	0.00429	1.73
26	15	7	5	0.53285	0.00520	1.84
27	15	8	5	0.59696	0.00732	1.90

But it should be noted that all three sets of data together are only the complete observation so the Tables were indexed as Table-1, Table-2 and Table-3 for set 1, set 2 and set 3 respectively. Here the observations were furnished when the experiments were conducted with the constant pulse off time 3μs. Initially The Peak current was varied 5A, 10A and then 15A for each Pulse on Time of 6μs, 7μs and 8μs. The MRR, SR and TWR were observed after machining 5 minutes of machining and recorded (Table-1). Similarly for constant pulse off time 4μs and 5μs the experimental procedures were repeated and tabulated in Table-2 and Table-3.

In an another experimental setup, Pulse on value has been maintained at 8 μs, Pulse off time 3μs and Peak current value is varied 5A, 10A and 15A. The MRR, SR and TWR have been observed after machining 5 minutes. Then similarly the experimentations were carried out for Pulse off time 4μs and for 5μs for peak current 5A, 10A and 15A at 6 μs.

RESULT AND DISCUSSIONS

The parameters influence investigation was carried out in three aspects such as the influence of input parameters with respect to the performance of MRR, TWR and SR.

Input parameters influence on material removal rate

MRR with respect to pulse on time

The Figure-1 reveals the MRR with respect to Pulse on Time in the order of 6μs, 7μs and 8μs. It is observed that if the peak current increases the MRR increase linearly as well as the increase of pulse on time. But the MRR response with respect to pulse off time minimal compared to peak current (Refer Figure-1a to Figure-1c).

MRR with respect to pulse off time

The Figure-2 shows that the MRR with respect to Pulse off Time in the order of 3μs, 4μs and 5μs. The results reveal that if the pulse on time increases the MRR increase steeply. The MRR increases with respect to increase of pulse off time as well as peak current. (Refer Figure-2a to Figure-2c)

MRR with respect peak current

The Figure-3 shows that the MRR with respect to peak current in the order of 5A, 10A and 15A. The result illustrates that if the pulse on time increases the MRR increase than the increase of pulse off time steeply. The MRR increases with respect to increase of peak current also (Refer Figure-3a to Figure-3c)

Input parameters influence in TWR

TWR with respect to pulse on time

The Figure-4 reveals the MRR with respect to Pulse on Time in the order of 6μs, 7μs and 8μs. The TWR increases with increase of peak current, as well as pulse on time. The increase, if pulse off time increases the TWR but less than other input parameters. (Refer Figure 4a to Figure 4c).

TWR with respect to pulse off time

The TWR is also increased with respect to increases of pulse on time as well as peak current. And some extent to increase of pulse off time (Refer Figure-5a to Figure-5c)

TWR with respect to peak current

The TWR is also increases with increase of pulse on time as well as peak current and some extent to increase of pulse off time (Refer Figure-6a to Figure-6c).

Input parameters influence machined surfaces

SR with respect to pulse off time

The roughness of machined surfaces was increased with increase of pulse on time and also increase of peak current. The pulse off time also influence in the SR and it is directly proportional to SR (refer Figure-7a to Figure-7c)

SR with respect to pulse on time

The increase of pulse on time steeply increases the surface roughness. The significant differences were observed with increases of peak current. The influence of pulse off time is increase of pulse off time increases the SR (Refer Figure-8a to Figure-8c).

SR with respect to pulse off time

The linear and steep raise response was observed when increase of pulse off time. The increase of surface roughness when increase of pulse on time. The influence of peak current increases the surface roughness greatly (Refer Figure-8a to Figure-8c).

Contribution of individual parameters

The percentage of contribution was examined. It is the percentage of its contribution by varying parameters and kept other parameters for example at the setting of Pulse on time 6µs, Pulse Off time 3 µs the variation of Peak Current from 5A to 15A. hence the contribution of the constant factors (Pulse on time 6µs , Pulse Off time 3 µs) for the responses 61.88% , 48.99% and 42.00% for MRR, TWR and SR respectively (refer Table-4).

CONCLUSIONS

The Factors contributions in machining Inconel 800 Nickel Based super alloy in EDM with silver coated copper electrode were experimentally studied and presented. The influence of input parameters like pulse on time, pulse off time and peak current in EDM on inconel 800 was discussed and presented graphically.

- The Maximum MRR contribution 75.33% in varying pulse off time from 3 to 5 when Peak current 15A and pulse on time 7µs. The other responses like TWR and SR are 64.81% and 66.45% respectively for the factors setting.
- The minimum TWR range contribution was observed at 11.55% in varying pulse off time from 3µs Peak current 5A when varying pulse on time7µs. To 8µs. The other responses like MRR and SR are 17.98% and 15.99% respectively for the factors setting.
- The minimum SR range contribution was observed at 15.99% at pulse off time 3µs, Peak current 5A when varying pulse on time7µs to 8µs. The other responses like MRR and TWR are 17.98% and 11.51% respectively for the factors setting.

Hence the high surface finish and minimum TWR can be obtained in the setting of Peak current 15A pulse off time 3µs and pulse on time 7µs. Similarly the High MRR can be achieved in setting Peak current 15A, pulse off time 5µs and pulse on time 7µs.

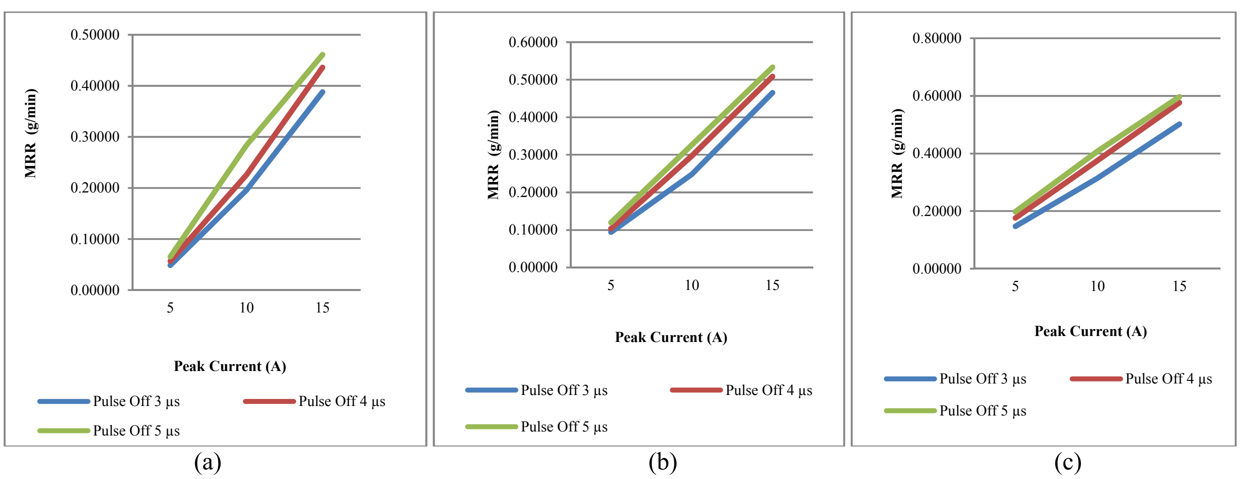

Figure-1. The MRR performance when pulse on time (a) 6µs, (b) 7µs and (c) 8 µs.

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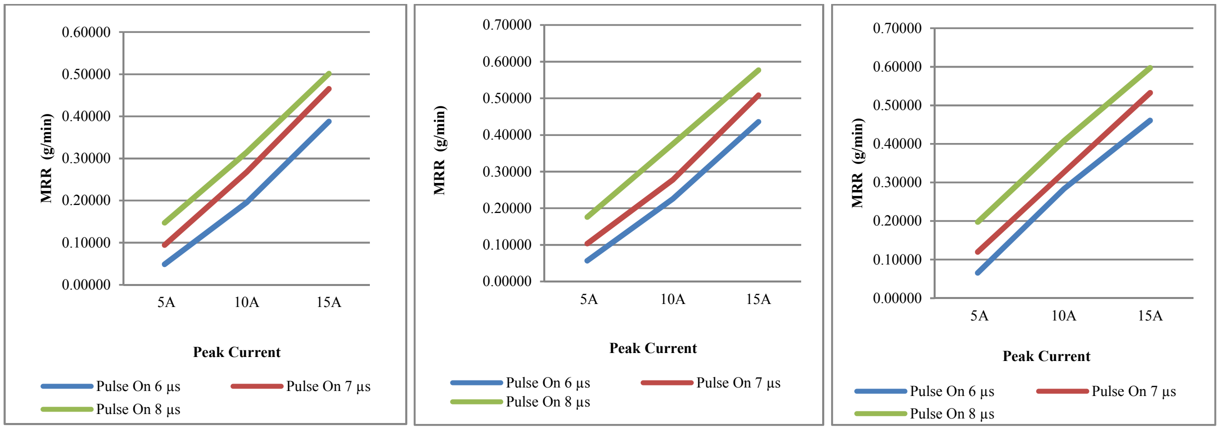
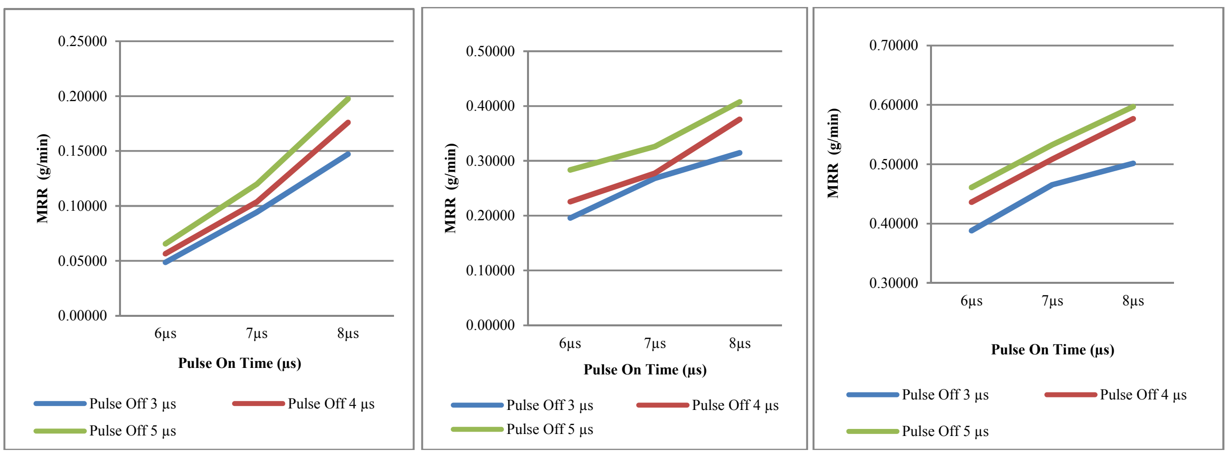


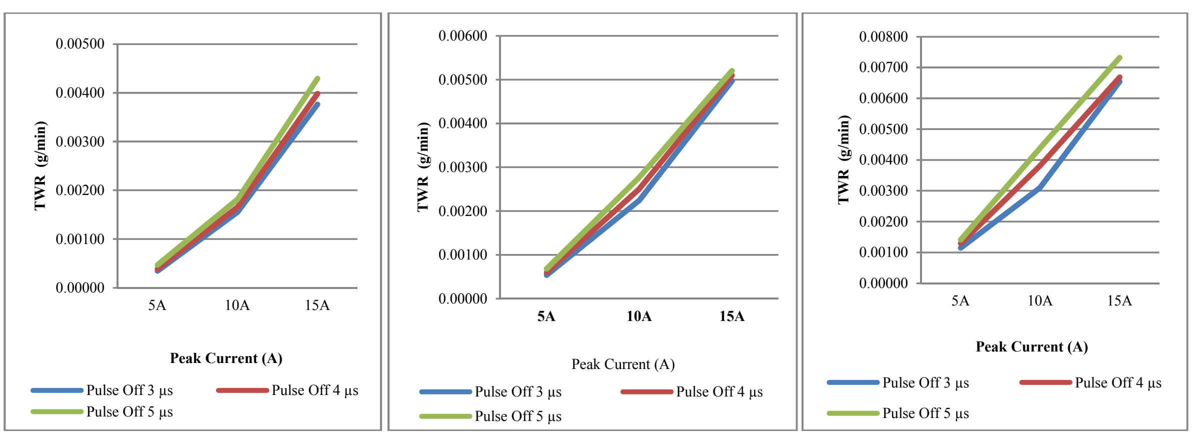
(a) (b) (c)

Figure-2. The MRR performance when pulse off time (a) 3µs, (b) 4µs and (c) 5 µs.



(a) (b) (c)

Figure-3. The MRR performance when peak current (a) 5A, (b) 10A and (c) 15A.



(a) (b) (c)

Figure-4. The TWR when pulse on time (a) 6µs, (b) 7µs and (c) 8µs.

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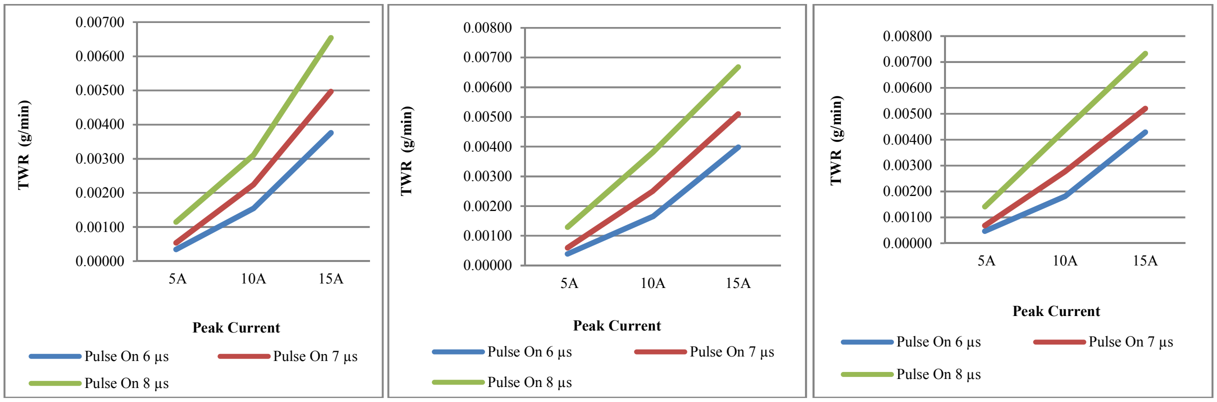
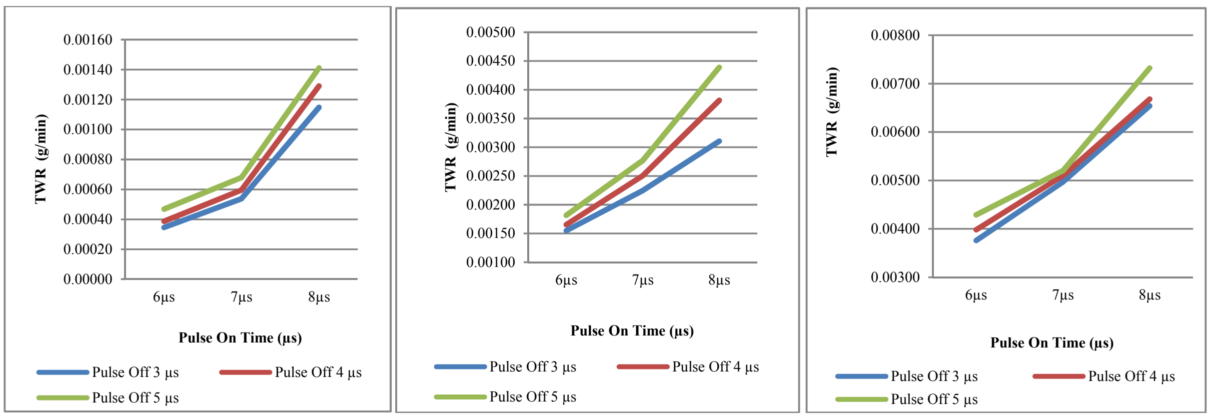


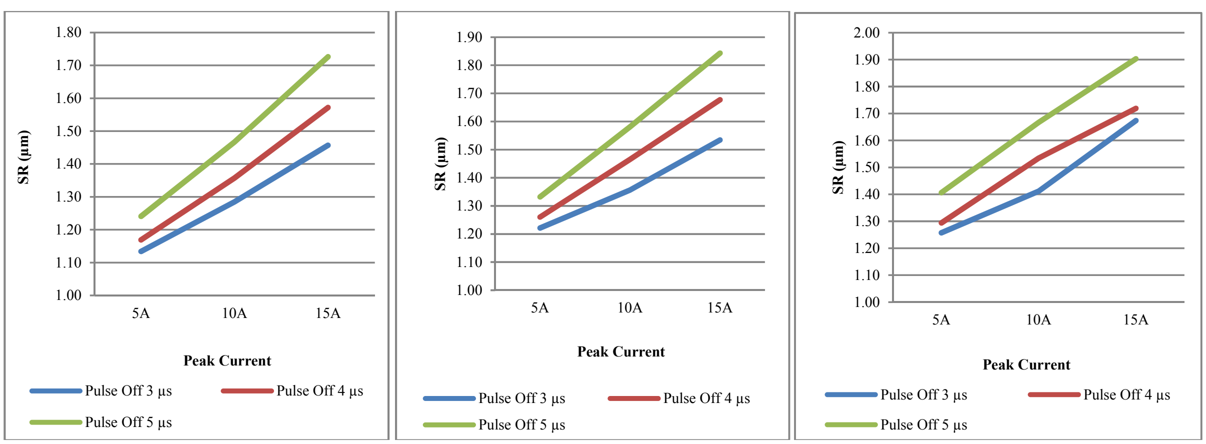
(a) (b) (c)

Figure-5. The TWR performance when pulse off time (a) 3µs, (b) 4µs and (c) 5µs.



(a) (b) (c)

Figure-6. The TWR when peak current (a) 5A, (b) 10A and (c) 15A.



(a) (b) (c)

Figure-7. The surface roughness when pulse on (a) 6µs, (b) 7 µs and (c) 8 µs.

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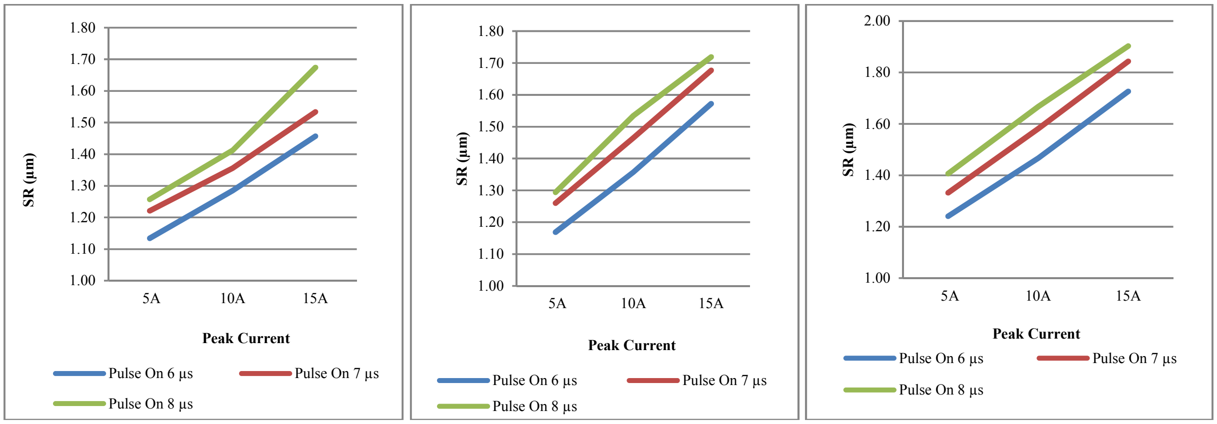
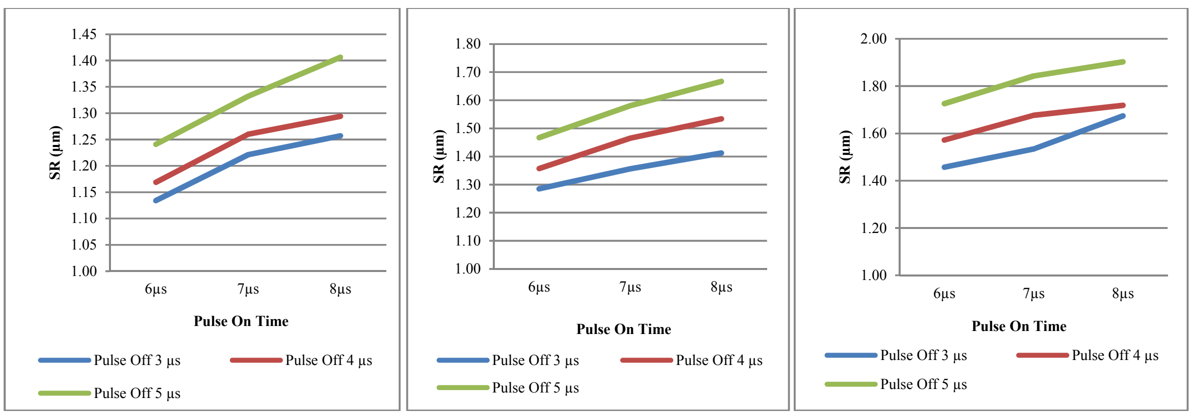


(a) (b) (c)

Figure-8. The surface roughness when pulse off time (a) 3µs, (b) 4 µs and (c) 5 µs.

SR with respect to pulse off time



(a) (b) (c)

Figure-9. The surface roughness when peak current is (a) 5A, (b) 10A and (c) 15A.

Table-6. Contribution of individual factors to responses.

Cases	**Constant parameters** (Factors)		**variable parameter** (Factor)	**MRR**	**TWR**	**SR**
				Percentage of contribution in responses		
1	Pulse On (6µs)	Pulse Off 3 µs	Peak Current	62%	49%	42%
2	Pulse On (6µs)	Pulse Off 4 µs	Peak Current	69%	52%	52%
3	Pulse On (6µs)	Pulse Off 5 µs	Peak Current	72%	55%	63%
4	Pulse On (7µs)	Pulse Off 3 µs	Peak Current	68%	64%	41%
5	Pulse On (7µs)	Pulse Off 4 µs	Peak Current	74%	65%	54%
6	Pulse On (7µs)	Pulse Off 5 µs	Peak Current	75%	65%	66%
7	Pulse On (8µs)	Pulse Off 3 µs	Peak Current	65%	77%	54%
8	Pulse On (8µs)	Pulse Off 4 µs	Peak Current	73%	77%	55%
9	Pulse On (8µs)	Pulse Off 5 µs	Peak Current	73%	85%	65%
10	Pulse Off (3µs)	Peak Current 5A	Pulse On Time	18%	12%	16%
11	Pulse Off (3µs)	Peak Current 10A	Pulse On Time	22%	13%	16%
12	Pulse Off (3µs)	Peak Current 15A	Pulse On Time	24%	14%	21%
13	Pulse Off (4µs)	Peak Current 5A	Pulse On Time	22%	22%	17%
14	Pulse Off (4µs)	Peak Current 10A	Pulse On Time	27%	31%	23%
15	Pulse Off (4µs)	Peak Current 15A	Pulse On Time	23%	37%	26%
16	Pulse Off (5µs)	Peak Current 5A	Pulse On Time	21%	40%	28%
17	Pulse Off (5µs)	Peak Current 10A	Pulse On Time	26%	39%	19%
18	Pulse Off (5µs)	Peak Current 15A	Pulse On Time	25%	43%	23%
19	Peak Current 5A	Pulse On 6µs	Pulse Off Time	62%	49%	42%
20	Peak Current 5A	Pulse On 7µs	Pulse Off Time	68%	64%	41%
21	Peak Current 5A	Pulse On 8µs	Pulse Off Time	65%	77%	54%
22	Peak Current 10A	Pulse On 6µs	Pulse Off Time	69%	52%	52%
23	Peak Current 10A	Pulse On 7µs	Pulse Off Time	74%	65%	54%
24	Peak Current 10A	Pulse On 8µs	Pulse Off Time	73%	77%	55%
25	Peak Current 15A	Pulse On 6µs	Pulse Off Time	72%	55%	63%
26	Peak Current 15A	Pulse On 7µs	Pulse Off Time	75%	65%	66%
27	Peak Current 15A	Pulse On 8µs	Pulse Off Time	73%	85%	65%

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