

Characteristics Investigation of Inconel-800 on EDM

Amit Kumar¹, Satish Kumar², Vikas Panchal³

Research Scholar, Dept. of Mechanical Engineering, HCTM TECHNICAL CAMPUS, KAITHAL, Haryana, India¹

Assistant Professor, Dept. of Mechanical Engineering, HCTM TECHNICAL CAMPUS, KAITHAL Haryana, India²

Assistant Professor, Dept. of Mechanical Engineering, SIET, AMBALA, Haryana, India³

ABSTRACT: The aim of the present study is to show the influence of different input parameters such as Pulse-on Time, Pulse-off Time and Peak Current on the mechanical properties during the Electrical Discharge Machine (EDM) of Inconel-800. The microstructure, EDM experiment are investigated in this study. The selected three input parameters were varied at three levels. On the analogy, nine experiments were performed based on L9 orthogonal array of Taguchi's methodology, which consist three input parameters. Analysis of variance (ANOVA) was employed to find the levels of significance of input parameters. Peak Current has greatest effect on MRR followed by Pulse-on Time and Pulse-off Time. Peak Current has greatest effect on TWR followed by Pulse-off Time and Pulse-on Time.

KEY WORDS: WEDM, EDM, Microstructure, Taguchi, ANOVA

I. INTRODUCTION

Electrical Discharge Machining is a non-traditional concept of machining. It has been widely used for making dies, punches and molds. It is also used in manufacturing of finished parts for automotive and aerospace industries and surgical components. It is also called spark erosion machining method because in this method material of work piece is removed by erosion effect by the electric spark. This process can be successfully employed to machine electrically conductive parts irrespective of their hardness, shape and toughness. The EDM machine has a tool and a work piece which is to be machined. The shape of tool used for spark generation is a replica of the shape of which is to be produced. The tool electrode and the work are held at an accurately controlled distance from one another, which are dependent on the operating conditions and referred to as spark gap. Both the tool and the work piece are dipped in a dielectric medium like kerosene, EDM oil etc.

EDM process consists of material removal through electric discharge. The phenomenon of metal removal by electrical discharges is quite complex to analyze. This is because of the fact that a number of interdependent variables have a controlled effect on the process. Till the date, there is no specific mechanism to describe the metal erosion process. Not even single conclusive theory has been established for this complex machining process. However, empirical evidences suggest the following events that occur during EDM machining. The applied voltage creates an ionized channel between the nearest points of the work piece and the electrode in the initial stage. In the next stage, the actual discharge takes place with a heavy flow of current and the resistance of the ionized channel gradually decreases. The high intensity of current continues to further ionize the channel and a powerful magnetic field is generated. This magnetic field compresses the ionized channel and results in localized heating.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

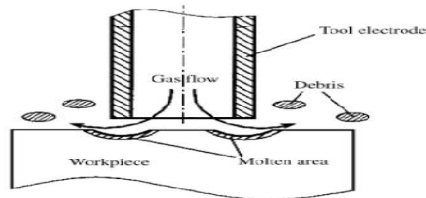


Figure No. 1 EDM Process

Selection of Process Parameters and their Level :

The determination of the parameters to investigate hinges upon the product or process performance characteristics or responses of interest. Several methods are suggested by Taguchi for determining which parameters to include in an experiment. These are explained in previous chapters. The identified process parameters are shown in the table 1.1. The selection of parameters of interest was based on some experiment preliminary. The following process parameters were thus selected for the present work:

- a) Pulse - on Time (T-on) A
- b) Pulse – off Time (T-off) B
- c) Current (amp) C

Table 1.1 Selection of process parameters with code & units

Sr. No.	Code	Process Parameter	Unit
1	A	Pulse-on Time	μ s
2	B	Pulse-Off Time	μ s
3	C	Peak Current	Amp

Selection of Material and electrode used :

INCONEL-800 is used for the experiment work. It is nickel based super alloy. It has excellent machine ability. It is high strength, toughness and ductility and low density as compare to other hard material.

Chemical Composition of material:

The following table shows the composition of Inconel – 800. Samples of size 200×15×6mm were cut with the help of WEDM. The chemical composition of mild steel sheet using for present study is shown in table 2.2

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

Table 1.2 Chemical Composition of Inconel – 800

Ni	Fe	Cr	Cu	Ti	Al	C	Mn	S	Si
30%	39%	19-23%	0.75%	0.15-0.60% max	0.15-0.60% max	0.1%	1.5% max	0.015	1.0% max

Pure copper electrode is used for experiment work. The length of electrode is 40mm.



Figure No. 3.4 Copper Electrode

Preparation of Inconel 800

To prepare the inconel 800 plate specimen, 1 inconel plate of dimension 200×15×6 mm was used. The plate is cut on the wire EDM. Wire cut electric discharge machine is a thermo-electric spark erosion process used for hard-to-cut materials.

II. METHODOLOGY

In this experimental work, the specimen Inconel-800 experiment at three different levels of process parameter i.e. Pulse-on Time, Pulse-off Time and Peak Current as shown in table 2.1. The objectives of the proposed work will focus on following aspects:

1. Pilot experimentation for selecting the range of process parameters that affects the machining characteristics such as material removal rate (MRR) and Tool wear rate (TWR).
2. Analyze and study the effect of different input parameters on material removal rate (MRR) and Tool wear rate (TWR).

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

Table-2.1: Process parameter and their levels

Parameters	Level 1	Level 2	Level 3
Pulse-on Time (μ s)	60	90	120
Pulse-off Time (μ s)	30	45	60
Peak Current (Amp)	2	6	10



Figure No.- 2 Cutting Inconel - 800 on WEDM



Figure No.-3 After cutting on WEDM Inconel-800 200×15×6mm

Fig. 2 shows the cutting of the sample from the big strip with help of WEDM. The working ranges of process parameter were fined by conducting trial run and satisfactory values obtained are used to conduct the experimental work. L9 orthogonal array is used for analysis purpose and standard table of three variables with three different levels of input parameters is shown in table 2.1 and actual value of selected input parameter arc shown in table 2.2.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

Table-2.2: L9 Orthogonal Array Design Matrix

Experiment Number	Pulse-on Time (μ s)	Pulse-off Time (μ s)	Peak Current (Amp)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table-2.3: L9 Matrix with Actual Value of Parameters

Experiment Number	Welding Current (Amp.)	Arc Voltage (Volt.)	Root Gap (mm)
1	60	30	2
2	60	45	6
3	60	60	10
4	90	35	6
5	90	45	10
6	90	60	2
7	120	30	10
8	120	45	2
9	120	60	6

The nine experiments were performed based on the L9 array. The effect of different parameters such as Pulse-on Time, Pulse-off Time and Peak Current of Inconel-800 is analyzed. The MRR and TWR of the specimen were checked carefully and the observed value of MRR and TWR with their S/N ratios are shown in table 5 and in table 6. Fig. 4 shows photograph of welded sample.



Figure No. 4 Workpiece After Machining

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

Table-2.4: Result for MRR

S. NO.	Pulse-onTime	Pulse-off Time	Peak Current	MRR	S/N Ratio
1	60	30	2	3.656	11.2601
2	60	45	6	10.086	20.0744
3	60	60	10	14.349	23.1364
4	90	30	6	13.827	22.8146
5	90	45	10	27.724	28.8571
6	90	60	2	3.43	10.7059
7	120	30	10	27.796	28.8796
8	120	45	2	3.687	11.3335
9	120	60	6	11.976	21.5662

Table-2.5: Result for Hardness

S. NO.	Pulse-on Time	Pulse-off Time	Peak Current	TWR	S/N Ratio
1	60	30	2	0.003	50.4576
2	60	45	6	0.228	12.8413
3	60	60	10	0.169	15.4423
4	90	30	6	0.082	21.7237
5	90	45	10	0.381	8.3815
6	90	60	2	0.033	29.6297
7	120	30	10	0.071	22.9748
8	120	45	2	0.013	37.7211
9	120	60	6	0.038	28.4043

III. RESULTS AND DISCUSSIONS

Fig. 5 shows the steps involved in the Taguchi analysis. Analysis of variance (ANOVA) is a statistical tool used to analyze the S/N ratios. In ANOVA setting, the observed variance in a particular variable is partitioned into components attributable to different sources of variation. Analysis of variance technique is used in order to check the adequacy of the model. The term “signal” represents the desirable mean value, and the “noise” represents the undesirable value. Hence, the S/N ratio represents the amount of variation, which presents in the performance characteristics.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

In the present study MRR and TWR of the Inconel-800 specimens were identified as the responses, therefore, “higher the better” for MRR and “Smaller the best” for TWR characteristic chosen for analysis purpose.

$$HB : S / N \text{ ratio} = -10 \log_{10} \left[\frac{1}{n} \sum_{i=1}^n yi^{-2} \right]$$

Where y_i represents the experimentally observed value of the with experiment, n is the repeated number of each experiment, \bar{y} is the mean of samples and s is the sample standard deviation of n observations in each run.

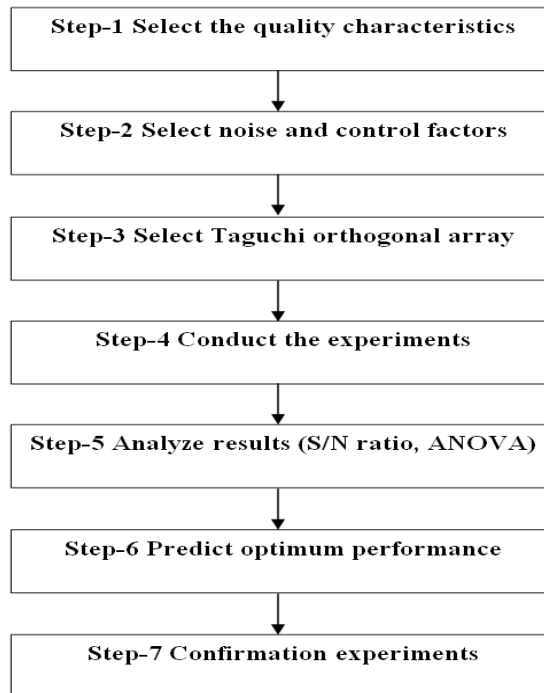


Fig-5: Steps for Taguchi's analysis

Material Removal Rate

MRR is calculated experimentally and Taguchi method is applied for analysis with the help of ANOVA. On basis of data analyzed, plots for signal-to-noise (S/N) ratio are shown in fig. 6. The calculated S/N ratio has been tabulated in table2.5.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

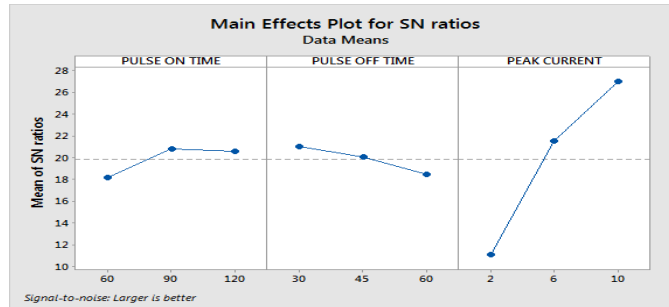


Fig-6: Effects of process parameters on MRR S/N ratio

The optimal process parameters have been established by analyzing response curves of S/N ratio. From Figure 6 it is concluded that third level of Peak Current (10 Amp), second level of Pulse-on Time (90 μ_s) and third level of Pulse-off Time (30 μ_s) gives the high MRR. Hence the optimum condition of input parameters is A2B1C3. Analysis of variance for S/N ratio is summarized in Table 7 and it is observed that Peak Current is the most prominent factor which effects MRR maximum with percent contribution of 93% followed by Pulse-on Time with percent contribution 3% then Pulse-off Time with percent contribution 2%.

Table-3.1: Analysis of Variance for Signal to Noise Ratio

Source	DF	Seq SS	Adj SS	Adj MS	F	P	PC (%)
Pulse-on Time	2	12.921	12.921	6.460	4	0.200	3
Pulse-off Time	2	9.751	9.751	4.875	3.02	0.249	2
Peak Current	2	389.277	389.277	194.638	120.44	0.008	93
Residual Error	2	3.232	3.232	1.616			0.7
Total	8	415.180					

The response values for S/N ratio for each level of identified factors have been listed in Table 3.1 which shows the factor level values of each factor and their ranking.

Table-3.2: Response Table for Signal to Noise Ratio of MRR

Level	Pulse-on Time (μ_s)	Pulse-off Time (μ_s)	Peak Current (Amp)
1	18.16	20.98	11.10
2	20.79	20.09	21.49
3	20.59	18.47	26.96
Delta	2.64	2.52	15.86
Rank	2	3	1

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

Tool Wear Rate

Tensile strength is calculated experimentally and Taguchi method is applied for analysis with the help of ANOVA. On basis of data analyzed, plots for signal-to-noise (S/N) ratio are shown in fig.7. The calculated S/N ratio has been tabulated in table 3.2.

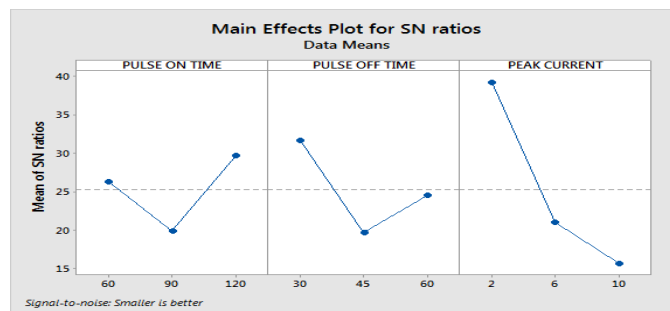


Fig-7: Effects of process parameters on TWR S/N ratio

The optimal process parameters have been established by analyzing response curves of S/N ratio. From Figure 7 it is concluded that third level of Peak Current (2 Amp), second level of Pulse-off Time (30 μ_s) and third level of Pulse-on Time (120 μ_s) gives the high MRR. Hence the optimum condition of input parameters is A3B1C1. Analysis of variance for S/N ratio is summarized in Table 3.3 and it is observed that Peak Current is the most prominent factor which effects MRR maximum with percent contribution of 67% followed by Pulse-on Time with percent contribution 16% then Pulse-off Time with percent contribution 10%.

Table-3.3: Analysis of Variance for Signal to Noise Ratio of TWR

Source	DF	Seq SS	Adj SS	Adj MS	F	P	PC (%)
Pulse-on Time	2	147.87	147.87	73.94	1.86	0.350	10
Pulse-off Time	2	221.39	221.39	110.70	2.78	0.265	16
Peak Current	2	923.47	923.47	461.73	11.59	0.079	67
Residual Error	2	79.66	79.66	39.83			5
Total	8	1372.40	1372.40				

The response values for S/N ratio for each level of identified factors have been listed in table 3.4 which shows the factor level values of each factor and their ranking.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

Table-3.4: Response Table for Signal to Noise Ratio for TWR

Level	Pulse-on Time (μ_s)	Pulse-off Time (μ_s)	Peak Current (Amp)
1	26.25	31.72	39.27
2	19.21	19.65	20.99
3	29.70	24.49	15.60
Delta	9.79	12.07	15.60
Rank	3	2	1

3.3 Microstructure Study

It can be visualized from the micrograph that Inconel 800 is uniformly distributed throughout the material in the matrix of Inconel. The substance does not exhibit any porosity indicated that it is a well compacted and sintered substance, as can be seen in the higher magnification micrograph. While analysis the process parameter pulse-on time 60 μ_s , pulse-off time 30 μ_s and peak current is 2 A. The peak current is most effective parameter for MRR.

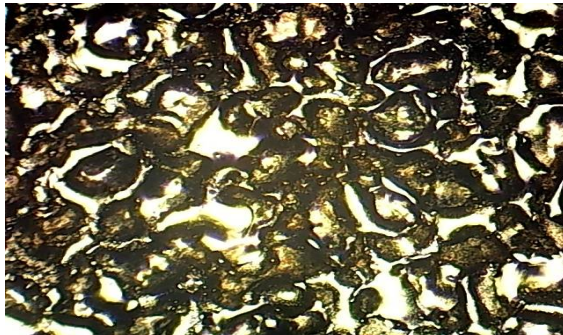


Fig-8: Microstructure of Spot-1



Fig-9: Microstructure of Spot-9

IV. CONCLUSION

In the present work Inconel 800 process parameters were optimized for increasing MRR of Inconel 800 and decreasing TWR of Copper Electrode. Three control parameters (Pulse-on Time, Pulse-off Time and Peak Current) used for this present work with a sample of 1 work piece. In this work L9 Orthogonal Array with 3 level used for find out the optimum result. Taguchi design of experiment technique is used for optimization of welding parameters. Minitab 15 software was used to generate S/N values and plots.

The present work can be concluded in the following steps:

1. Peak Current has greatest effect on MRR (T_{on} , T_{off} and I_p) followed by Pulse-on Time and Pulse-off Time.
2. For TWR Peak Current has greatest effect followed by Pulse-off Time and Pulse-on Time.

REFERENCES

1. Gang Wang and Yan Shan, "Compensation of electrode orbiting in electrical discharge machining based on non-uniform offsetting", International Journal of Machine Tools & Manufacture, Science Direct-Elsevier, pp. 1628–1634, 2005.
2. H. Ramasawmy and L. Blunt, "Investigation of the effect of electrochemical polishing on EDM surfaces", International Journal of Advanced Manufacturing and Technology, Springer vol. 31 pp. 1135–1147, 2007.
3. Jose Carvalho Ferreira, "A study of die helical thread cavity surface finish made by Cu-W electrodes with planetary EDM", International Journal of Advanced Manufacturing and Technology, Springer vol. 34 pp. 1120–1132, 2007.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

4. Hung Rung Shih and Kuen Ming Shu , “A study of electrical discharge grinding using a rotary disk electrode”, International Journal of Advanced Manufacturing and Technology, Springer vol.38 pp. 59–67, 2008.
5. Jose Duarte Marafona, “Black layer affects the thermal conductivity of the surface of copper–tungsten electrode”, International Journal of Advanced Manufacturing and Technology, Springer vol.42 pp. 482–488, 2009.
6. XieBao-cheng, Wang Yu-kui, Wang Zhen-long and Zhao Wang-sheng, “Numerical simulation of titanium alloy machining inelectric discharge machining process”, Transactions nonferrous Metal Society of China, vol21 pp. 434-439, 2011.
7. Sanjeev Kumar, Rupinder Singh, Ajay Batish and T.P. Singh , “A mathematical model to predict material removal rate during electric discharge machining of cryogenically treated titanium alloys”, Journal of Engineering Manufacture pp. 1–15, 2014.
8. Sanjeev Kumar, Rupinder Singh, Ajay Batish and T.P. Singh , “ Study the Surface Characteristics of Cryogenically Treated Tool-Electrodes in Powder Mixed Electric Discharge Machining Process”, Materials Science Forum Vol. 808 pp. 19-33, 2015.