Optimization of Process parameters in EDM for Machining of Inconel 718 using Response Surface Methodology

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Abstract- Electrical discharge machining, commonly known as EDM, is a process that is used to remove metal through the action of an electrical discharge of short duration and high current density between the tool and work piece. There are no physical cutting forces between the tool and work piece. Inconel 718 is one of the alloys that have relatively poor machinability in the conventional machining processes; due to its work-hardening nature, retention of high strength at high temperature and low thermal conductivity. For Inconel alloy, EDM is a preferred material removal process due to its advantages like reduced machining stresses, lesser work-hardening effects and lesser metallurgical damage. This paper reports the results of an experimental investigation carried out to study the effects of machining parameters such as current, voltage and pulse on time on material removal rate and tool wear rate in electrical discharge machining of Inconel 718 by using brass electrode.

Response surface analysis and ANOVA techniques are used for data analysis while RSM's D-Optimal Method is used to solve the multi-response optimization. To validate the optimum levels of the parameter, confirmation run was performed by setting the parameters at optimum levels. It is observed that current is most significant parameter for material removal rate and less significant for tool wear rate followed by pulse on time and voltage.

Keywords- Electrical discharge machining, brass, response surface methodology, Inconel 718, material removal rate, tool wear rate.

I. INTRODUCTION

At the present Electrical discharge machining is widespread technique used in industry for high precision machining for all types of conductive materials such as metals, metallic alloys, ceramic materials, super alloys etc. of whatever the intensity of hardness [1]. EDM is used in the industries like aeronautics, automobiles, nuclear reactors, missiles, turbines etc. materials like high strength temperature resistant alloys which have higher strength, corrosion resistance, toughness and other diverse properties [2]. The major advantage of EDM is that the machining process enables us to obtain components with desired shape and closer dimensional tolerance in a shorter time, compared to that in case of traditional machining process [3]. As both electrode and workpiece being electrically conductive possess sufficient amount of free electrons, this free electrons are plugged towards the workpiece these emitted electrons stick on dielectric molecules and ionize them. Now in spark gap there are free electrons and ions which undergo collusion due to avalanche motion between them leads to development of new state of matter called "plasma". Thus plasma channel is set up between tool and workpiece and the temperature goes high around 8000^0C-12000^0C. Thus surface layer of workpiece is rapidly melted by a spark at each charge point. In this way, small volume of workpiece material is removed by mechanism of melting and vaporization because of sparking [4]. EDM parameters namely voltage range, impulse frequency, dielectric fluid pressure, type of flushing and electrode material are the most affecting parameters. It was found that these parameters have significant influence on machining characteristics such as machining rate, tool erosion rate, volumetric wear ratio and surface finish. Among the electrode material (brass, copper and graphite) used graphite exhibits superior qualities with respect to machining characteristics expect for surface finishing [5]. Inconel 718 is precipitation-hardened nickel chromium alloy, it contain substantial levels of iron, molybdenum, nibonium, trace amount of titanium and aluminum processing high strength and temperature resistance combined together establishing the process capabilities of EDM for machining Inconel 718 and optimizing the process important, since it has wide specialized engineering application[6].

II. EXPERIMENTAL SET UP

During this study, a series of experiments on EDM of Inconel 718 was conducted on ZNC-50 electric discharge machine to examine the effects of input machining parameters such as current, voltage and pulse on time on material removal rate and tool wear rate.

A. Machine tool and dielectric medium-

All the experiments where performed on die sinking 'ZNC-50 ELECTRONICA EDM' machine. For the experimentation purpose "RUST LICK-30" oil having dielectric strength 45 kW was used as a dielectric medium at a flushing pressure of 0.25 kg/cm^3.The dielectric fluid should possess two conflicting properties that is the spark conductor that must ionize under the applied voltage at the same time it should not get break down in the spark gap. It should acts as flushing medium that carries away the melted material.

B. Workpiece material

The work material chosen for the experimental purpose was Inconel 718. Total 20 holes are machined by using brass electrode of diameter 10 mm over 4 plates of size (90×20×3.15) mm. Inconel 718 has wide specialized engineering applications, like components of nuclear reactor, space craft, steam turbine and propulsion system. The chemical composition & Physical properties of Inconel 718 are listed in table.

(a) (b)

Figure 1. (a) Machined Work Piece (b) Brass Electrode

Table 1- Physical Properties of Inconel 718

Coefficient of Expansion (^{0} C)	**20-100**
Melting point (^{0} C)	**1336**
Modulus of Rigidity (KN/mm^2)	**77.2**
Modulus of Elasticity (KN/mm^2)	**204.9**

C. Electrode material

The electrode material used in this research is brass of diameter 10 mm is shown in figure1. (b)

D. Machining parameters and their levels

Table-2 Levels and values of Operating Parameter

Parameters	**Coding**	**Levels**		
		-1	**0**	**1**
Voltage (V)	**A**	**80**	**100**	**120**
Current (A)	**B**	**30**	**40**	**50**

Pulse-on time (µS)	**C**	**500**	**750**	**1000**

There are large numbers of factors to consider within the EDM process, but in this work current, voltage and pulse on time have only been taken into account as design factors. The reason why these three factors have been selected as a design factors is that, they are the most affecting factors.

The current (I) depends on the different power levels that can be supplied by the EDM machine generator. It represents the maximum value of the discharge current intensity. Voltage (*V*) is the value of the electric tension applied between the part to be machined and the electrode just before the discharge is produced. The intensity values used in the EDM machine programming are power levels of the generator, these corresponding with values of the peak intensity, which is applied between the electrode and the part to be machined. Pulse on time or on-time (T_{on}) is the duration of time (in µs) the current is allowed to flow per cycle.

E. Response variables selected

Material removal rate and tool wear rate are considered as a response parameters they are defined as follows:

The material removal rate is expressed as the ratio of the of weight of the workpiece before and after the machining to machining time as shown in eq. (1)

$$\text{MRR} = \frac{\text{Wtb} - \text{Wta}}{t} \qquad (1)$$

Where,

W_{tb} - Weight of workpiece before the machining (gm)

W_{ta} - Weight of workpiece after the machining (gm)

t - Time consumed for the machining (min)

The tool wear rate is expressed as the ratio of the of weight of the tool before and after the machining to machining time as shown in eq. (2)

$$\text{TWR} = \frac{\text{Wtb} - \text{Wta}}{t} \qquad (2)$$

Where,

W_{tb} - Weight of tool before the machining (gm)

W_{ta} - Weight of tool after the machining (gm)

t - Time consumed for the machining (min

II. METHOD OF EXPERIMENTATION

Design of Experiment (DOE) is an efficient experiment planning process that allows the data obtained to be analyzed, valid conclusions to be drawn and objectives to be set. DOE is used to determine the appropriate number of tests and the experimental conditions necessary to obtain the desired goal of analyzing which factor of the process influences the response variables. The most common design consists of running the test with all the possible combinations of variables at predetermined levels.

A well-planned design of experiment can substantially reduce the number of experiments and for this reason a CCD with three levels was selected to develop the linear model. In the present investigation, experiments were performed on the basis of the Design of Experiments (DOE) technique. The design chosen was linear design 2^3 with 8 cube point, 6 center point in cube, 6 axial points.

A. Response surface methodology

Response surface methodology (RSM) is a collection of mathematical and statistical techniques useful for analyzing problems in which several independent variables influence a dependent variable or response, and the goal is to optimize this response. In many experimental conditions, it is possible to represent independent factors in quantitative form as given in equation 3. Then these factors can be thought of as having a functional relationship with response as follows.

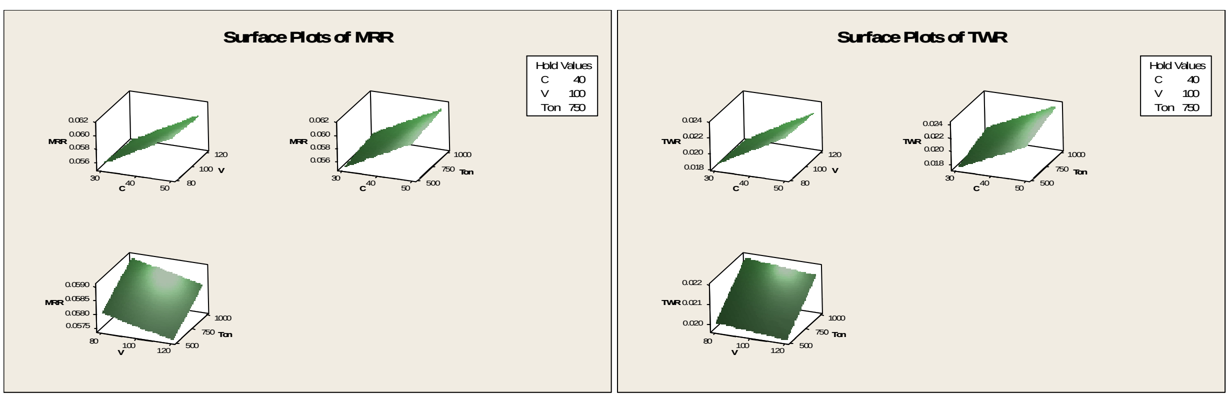
$$Y = \phi\,(X_1, X_2, X_{3\ldots}X_k) \pm \text{er} \qquad (3)$$

III. EXPERIMENTAL RESULTS AND OPTIMIZATION

RSM approach was employed for designing as well as for finding out optimal solutions. The following results are obtained as shown in table 3.

Table-3 Experimental results

Expt.No.	Process Parameters			Response Parameters	
	X_1	X_2	X_3	MRR (grm/min)	TWR (grm/min)
1	30	100	750	0.0560	0.0185
2	40	80	750	0.0581	0.0208
3	50	100	750	0.0610	0.0232
4	40	100	500	0.0577	0.0201
5	40	100	750	0.0579	0.0212
6	40	120	750	0.0580	0.0207
7	40	100	750	0.0579	0.0207
8	40	100	1000	0.0588	0.0219
9	30	120	500	0.0544	0.0170
10	30	80	1000	0.0568	0.0195
11	40	100	750	0.0579	0.0207
12	50	80	500	0.0611	0.0222
13	40	100	750	0.0579	0.0212
14	50	120	1000	0.0614	0.0239
15	40	100	750	0.0579	0.0212
16	50	120	500	0.0604	0.0221
17	40	100	750	0.0579	0.0207
18	30	120	1000	0.0560	0.0190
19	40	80	1000	0.0587	0.0218
20	30	80	500	0.0559	0.0179



(a) Surface plot for MRR (b) Surface plot for TWR

Figure- 2 Surface Plots

The surface plot between current, voltage and pulse on time for MRR and TWR are shown in figure.2 (a) and (b) respectively. Figure shows that with the increase of current and pulse on time the MRR and TWR increases gradually. TWR is decreases with increase in voltage because deposition of carbon layer on tool and workpiece . The increase in MRR with the increase in discharge current is because the spark discharge energy is increases to facilitate the action of melting and vaporization, and advancing the large impulsive force in the spark gap, thereby increasing the MRR. Therefore, the larger current results in deeper craters, which increase the material removal and tool wear rate.

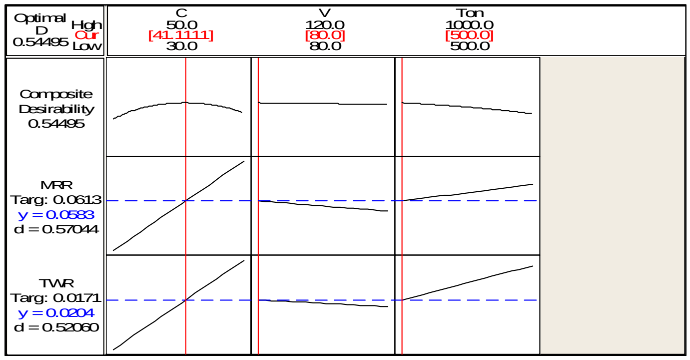


Figure-3 Optimization plot for material removal rate and tool wear rate

Table-4 Comparison between Predicted and Experimental values

Contents	Response	Values
Predicted values (gms/min)	**MRR**	**0.0583**
	TWR	**0.0204**
Experimental values(gms/min)	**MRR**	**0.0598**
	TWR	**0.0194**
Error in % for MRR	**MRR**	**2.5**
	TWR	**4.43**

The figure 3 shows that the optimizations plot for material removal rate and tool wear rate. The ultimate objective of our work was to maximize the MRR and minimize the TWR. The desirability approach was used for finding out the optimum values of material removal rate and tool wear rate. From the graph it clear that the highest value of MRR is 0.0583 gm/min and the lowest value of TWR is 0.0204 gm/min which is obtained at optimum predicted values of input parameters.

The final step of experimentation is the confirmation experiment. The purpose of the confirmation experiment is to validate the conclusions drawn during the analysis phase. After determining the optimum levels, a new experiment is design and conducted with optimum levels of the machining parameters. Experimental value of material removal rate is 0.0598 gms/min, found very close to the predicted value of 0.0583 gms/min and experimental value for tool wear rate is 0.0194 gm/min, found very close to predicted value of 0.0204 gm/min. The percentage variation between predicted values and experimental values for material removal rate and tool wear rate for brass electrodes are 2.50 % and 4.43 % respectively.

The percentage error between the actual and predicted values of the responses fall below 5 %, which shows that the optimized values of EDM process parameters obtained are good enough to have agreement between the predicted and experimental values ensuring that process can be carried out for optimum setting for good results.

V. CONCLUSION

The following conclusions are drawn from the investigation to describe the relation of various machining parameters and their effects on output parameters while machining of Inconel 718.

- Current is most affecting parameters for both MRR and TWR.
- Material removal rate and tool wear rate increases as the current and pulse on time increases. While material removal rate and tool wear rate decreases as the voltage increases.
- The optimal values of process parameters which have composite desirability 0.54 are current 41.11 (A), voltage 80(V) and pulse on time 500 (μs).

REFERENCES

[1] I. Puertas, C.J. Luis, "A study on the electrical discharge machining of conductive ceramics", Journal of Materials Processing Technology 153–154 (2004) 1033–1038.

[2] M Manohar, T Selvaraj,D , D Sivakumar, Shibu Gopinath and Koshy M George, "Experimental study to assess the effect of Electrode bottom profiles while machining Inconel 718 through EDM Process", Procedia Materials Science 6 (2014) 92 – 104.

[3] B.V. Manoj Kumar, J. Ramkumar, Bikramjit Basu, S. Kang, "Electro-discharge machining performance of TiCN-based cermets", International Journal of Refractory Metals & Hard Materials 25 (2007) 293–299.

[4] Mr. N. S. Payaghan, Mr. S. B. Ubale, Dr. M. S. Kadam, "Modeling and Analysis of Effects of Machining Parameters on MRR in EDM Process of Copper Tungsten Metal Matrix Composite (MMC)", International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 6, June – 2014.

[5] Santanu Dey, Dr. D.C.Roy, "Experimental Study Using Different Tools/Electrodes E.G. Copper, Graphite on M.R.R of E.D.M Process and Selecting The Best One for Maximum M.R.R in Optimum Condition" International Journal of Modern Engineering Research (IJMER) Vol.3, Issue.3, May-June. 2013 pp-1263-1267.

[6] M Manohar, T Selvaraj,D , D Sivakumar, Shibu Gopinath and Koshy M George, "Experimental study to assess the effect of Electrode bottom profiles while machining Inconel 718 through EDM Process", Procedia Materials Science 6 (2014) 92 – 104

[7] C.J. Luis, I. Puertas, G. Villa, "Material removal rate and electrode wear study on the EDM of silicon carbide", Journal of Materials Processing Technology 164–165 (2005) 889–896.

[8] Sameh S. Habib, "Study of the parameters in electrical discharge machining through response surface methodology approach", Applied Mathematical Modeling 33 (2009) 4397–4407.

[9] Pratik A. Patil, C.A. Waghmare, "Optimization of Process Parameters in Wire-edm Using Response surface methodology" , Proceedings of 10th IRF International Conference, 01st June-2014, Pune, India, ISBN: 978-93-84209-23-0.

[10] Somnath M. Kale, D.S.Khedekar, "Optimization of Process Parameters in Electric Discharge Machining Of Inconel 718 by Using Copper Electrode", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 3 Ver. III (May- Jun. 2016), PP 51-55.

[11] M. B. Patel, P. K. Patel, J. B. Patel, ,Prof. B. B. Patel, " Application of Response Surface Methodology For Determining MRR and TWR Model In Die Sinking EDM", of AISI 1045 Steel International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 Vol. 2, Issue6, November- December 2012, pp.1227-1231.