Experimental Analysis of the Influence of Discharge Gap on EDM Performance

Jestin Jose and Lijo Paul

May 10, 2020

Available online at www.sciencedirect.com

ScienceDirect

materialstoday: PROCEEDINGS

International conference on Integration of Advanced Technologies for Industry 4.0 (ICIATI)

Experimental analysis of the influence of discharge gap on EDM performance

Jestin Jose, Lijo Paul

Department of Mechanical Engineering, St. Joseph's College of Engineering and Technology, Palai 686579, India

Abstract

In order to reduce the machining time and improve the surface quality of holes, a high speed self adjusting electrical discharge machining (EDM) approach is needed with independent flushing system that were able to remove the debris in the machining process. With the change in the gap distance and depth of the hole drilled, the electrode automatically adjusts the gap with the help of a linear actuator. For that, the optimum gap distance for getting maximum result is crucial. Taguchi L27 orthogonal array technique is used for the preliminary experimental analysis. The study revealed that discharge gap which is proportional to the gap voltage is the most influential parameter that affects the surface finish and material removal rate. The formation mechanism of the hole in the copper plate had found out, in order to get the optimum gap distance for the maximum MRR, TWR, and ROC. The results from the comparison experiment shows that the best result will be get at 0.5mm gap distance and this can be taken as the optimum gap distance for the automatic feeding mechanism. In addition, low voltage and current would benefit for the EDM process working in micro level and for the removal of the recast layer.

Keywords: EDM, MRR, TWR, ROC, Automatic Feeding Mechanism

1. Introduction

Today the conventional machines are replaced by the EDM machines in large and small scale industries because of the significant importance and advantageous of micro EDM. The burr free nature of the components with minimum heat affected zone and better surface finish are some of them. Micro EDM has the ability to machine the particles in the micro level with better accuracy. Discharge gap or gap distance is the distance between the tool and the workpiece. Most of the study revealed that the discharge gap which is proportional to the gap voltage is the major influencing parameter for increasing surface finish and MRR. The existence of the debris in the machining gap also adversely affects to the output. This debris will result in uneven sparking and drastically affect to the surface finish of the particle. The variations in the gap distance will proportionally made changes in the discharge voltage and this will seriously affect during the smooth machining of high accuracy parts. To increase the machining quality this gap distance has to be maintained by finding out the optimum gap distance for that condition. Set of experiments are done on an indigenously prepared EDM machine with different discharge gaps by adopting L27 series. A comparative study is made and results are analyzed.

2. Experimental Setup

The experimental setup is developed with the help of mechanical, electrical and electronic systems. The detailed discussion of specification and attributes of these are mentioned.

2.1 Mechanical System

The mechanical system is made up of mild steel and mainly consists of a mechanical frame and a feeding mechanism. The mechanical frame consisting of a bed and column will provide the support for fixing the acrylic container and also the feeding mechanism. The linear actuator will control the feeding of the tool holder known as Z feeding (longitudinally) which is fixed at the end of the linear actuator. The linear actuator will move up and down with the help of a dc motor when the polarity is changed. The DPDT switch are using here for adjusting the discharge gap. The submersible pump which is dipped in the dielectric fluid will help to jet flush the liquid to the machining area in order to remove the debris.

2.2 Electrical System

Electrical system is very important for electric discharge machining (EDM) setup, as machining is taking place through the spark generation. To obtain good result the machining values of voltage and duty ratio and frequency is very important. For studying and conducting this experiment, mainly needed electric equipments are, dc power source, dual dc regulated power supply, function generator. Voltage is one of the input parameters for conducting the experiment. For optimizing the results, we need to vary the voltage between 35V to 45V. This is possible by using the power source. For this experiment we use DC power source of 50V. The terminals are connected to the power circuit. Frequency is another process parameter for the micro electric discharge machining. A function generator are used develop several types of waveforms with different frequencies. Here we vary frequency from 2 KHz to 6KHz. An additional dc power source is given for the working of linear actuator. The duty ratio is an important parameter for the smooth functioning the micro EDM. So here we are using a square wave. We can adjust the duty factor from 60-80% with the help of an oscilloscope.

2.3 Electronic System

Electronics is mainly used in this setup to drive the linear actuator as well as to control the input parameters. The main circuits used in these experiments are power circuit and linear actuator circuit. The power circuits are used to generate spark at the tip of the tool. Here tool will act as the cathode and workpiece as the anode. The negative end from the dual dc power supply will connect to the tool through the power circuit and the positive end to the workpiece directly. For the smooth functioning of the power circuit 5V supply will be given from the regulated dc power supply. The movement of the linear actuator is done with the help of a Dual Pole Dual Throw (DPDT) switch for adjusting different discharge gap manually. The automatic feeding control can be later set with an integrated chip circuit which will maintain constant optimum gap throughout the machining process.

2.3 Working Tool

The working tool here used is an alloy of tungsten and copper. Here the tool is chosen which have higher erosion index as compared to that of workpiece. Here the tool wire diameter used for the experiment is 0.6mm. The tool is hold with the help of a micro chuck of brass material which is fixed at the end of the linear actuator.

2.4 Workpiece

In this experiment the workpiece used is copper plate of 0.2mm thickness. The EDM process involves the creation of a plasma channel in the form of a spark discharge between the workpiece and electrode, which heats the surfaces of the workpiece and electrode. The workpiece is kept in the acrylic container which is filled with deionised water. Some of the material is heated beyond its boiling point and is removed by vaporization, while other material is only heated beyond its melting temperature and forms a molten pool on the material surface, which is cooled in the deionised water to form debris.

2.5 Dielectric Medium

The dielectric medium is unavoidable in the EDM process since it help to contribute an insulating medium against unanticipated discharge and is used to flush off the heat and debris produced in the machining area. The dielectric medium begins to ionize in the inter-electrode gap in the presence of the high electric fields that develop and the process of dielectric breakdown begins. This dielectric breakdown helps in generating spark at the inter electrode gap.

3. Experimental Procedure

The experiments were carried out on an indigenously prepared EDM machine. Here the input parameters like voltage, frequency, duty factor and gap distance are kept constant for doing the each experiment consistent. To study the entire parameter space with only a small number of experiments, Taguchi method uses a special design of orthogonal arrays. Here the L27 orthogonal array is used. Minitab-17 software is used for the design of experiments and for the statistical analysis of the results. The workpiece used is copper (0.2mm thickness) and the tool electrode is copper tungsten alloy (dia. 0.6mm) which have higher erosion index as compared to that of workpiece. De-ionised water was used as the dielectric fluid. A jet flushing was applied with the help of a submersible pump(flow rate 200L/hr) at regular intervals inorder remove the debris from the machining area.

The weight of each workpiece and the tool is measured before and after the experiment. Total 27 experiments are done. Four values for each input parameters are given to complete the experiment. A square wave function is used in the oscilloscope which is connected to the function generator. The time for machining a micro hole with this setup will vary from 20-45min. The values are noted in a Taguchi table and calculations are done. From the difference in the weight of the workpiece and tool, MRR and TWR are calculated. With the help of a tool maker’s microscope, the microscopic images of through holes were found out. From this microscopic view the diameter of the hole can be find out. The difference of the through hole diameter and tool diameter will give Radial Over Cut (ROC).

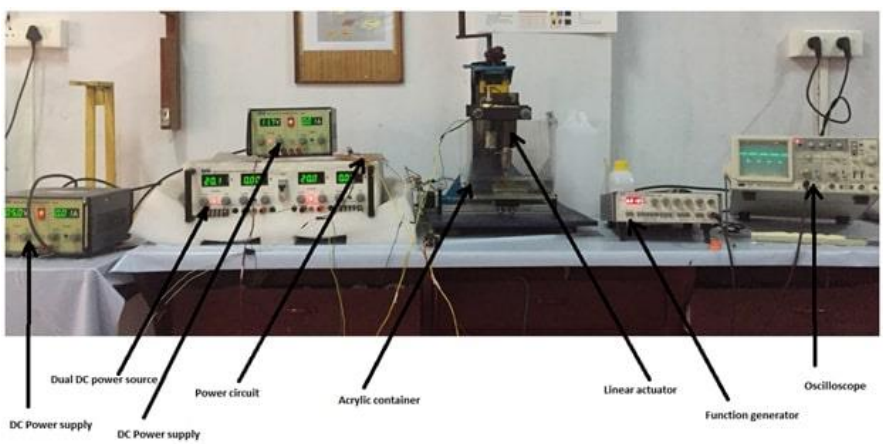

Fig. 1. Overall EDM setup

Pareto analysis is done to determine the parameter influence in the experiment. The influence of parameters such as voltage, frequency and duty factor in changing the MRR, TWR and ROC is evaluated. This analysis includes Taguchi’s method based on parametric optimization technique to quantitatively determine the effects of various machining parameters on the quality characteristics of EDM process and to find the optimum parametric condition for obtaining best machining criteria. In this analysis, the performed parametric design of experiment is based on the selection of an appropriate standard orthogonal array. The analysis by Pareto optimization is carried out to study the relative influence of the machining parameters on the MRR of the EDM machined material.

4. Results and observation

The details of the Taguchi L27 orthogonal array and respective performance characteristics for each setting of process parameters are listed in Table 1. Pareto analyses have done for the three gap distances, the optimization and comprehensive analysis of the concerned results have done from that. The MRR, TWR and ROC are recorded in the table. The microscopic views of the specimen and calculation of the hole diameter have done.

Table 1

EDM machined values

Sl. No.	Voltage (V)	Frequency (KHz)	Duty Factor (%)	Gap Distance (mm)	MRR $\times 10^{-5}$ (mg/min)	TWR $\times 10^{-5}$ (mg/min)	ROC (mm)
1	35	2	60	0.5	5.5	0.1	0.6
2	35	2	60	0.5	5.66	0.104	0.171
3	35	2	60	0.5	6.12	0.103	0.706
4	35	4	70	1	4.88	0.106	0.58
5	35	4	70	1	4.75	0.11	0.254
6	35	4	70	1	5.67	0.073	0.289
7	35	6	80	1.5	5.94	0.107	0.613
8	35	6	80	1.5	5.8	0.096	0.499
9	35	6	80	1.5	5.24	0.13	0.216
10	40	2	70	1.5	5.4	0.098	0.57
11	40	2	70	1.5	5.66	0.1	0.602
12	40	2	70	1.5	5.3	0.108	0.716
13	40	4	80	0.5	6.3	0.07	0.294
14	40	4	80	0.5	6.23	0.098	0.59
15	40	4	80	0.5	6.37	0.09	0.342
16	40	6	60	1	6.01	0.094	0.613
17	40	6	60	1	6.14	0.114	0.463
18	40	6	60	1	6.15	0.127	0.231
19	45	2	80	1	5.07	0.1	0.6
20	45	2	80	1	5.28	0.102	0.611
21	45	2	80	1	5.37	0.123	0.707
22	45	4	60	1.5	5.46	0.09	0.312
23	45	4	60	1.5	5.43	0.087	0.63
24	45	4	60	1.5	6.31	0.13	0.399
25	45	6	70	0.5	7.94	0.107	0.645
26	45	6	70	0.5	7.69	0.105	0.499
27	45	6	70	0.5	6.33	0.12	0.182

The main effect plots for MRR, TWR and ROC have developed. The graphs are obtained by using the data obtained from the experiments. The mean values of the four randomized runs of the experiment have recorded. The main effect plot of the tested factors of the performance characteristics are shown in the Fig. 2. For MRR, larger is better and in the case of TWR and ROC smaller is the better. From the graph it can be seen that, for the gap distance of 0.5mm, maximum MRR is possible. Smaller TWR and ROC can also be achieved at the 0.5mm gap distance. The gap distance of 1mm will only provide lesser efficiency with minimum MRR and maximum TWR. Variations of the other parameters also influence in the MRR, TWR and ROC.

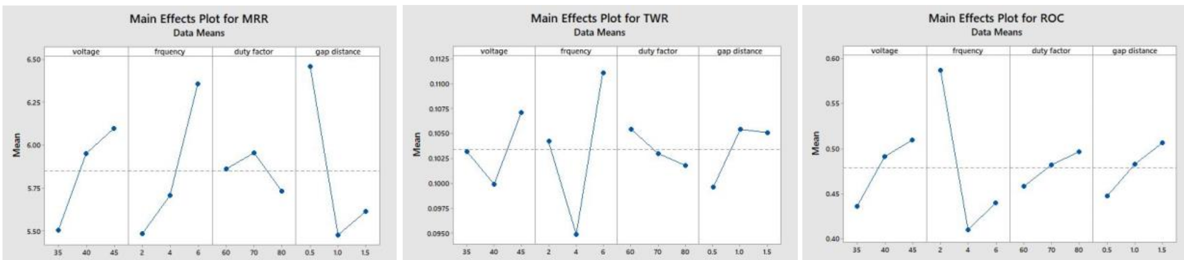

Fig. 2. Effect of MRR, TWR and ROC on EDM

As voltage increases, there is a tremendous increase in MRR and ROC, but TWR decreases and then increases. This is because of higher discharge energy of spark during the machining. Higher frequency and voltage will result in an aggressive machining process. Decreasing the gap distance would minimize the difference between through hole diameter and tool diameter. The increase in duty factor will result in the increase of prolonged spark discharge and there by more erosion of the material causing higher ROC. The results disclose that maximum MRR and minimum TWR and ROC are not possible with the same setting of parameters for a considered union of tool and workpiece.

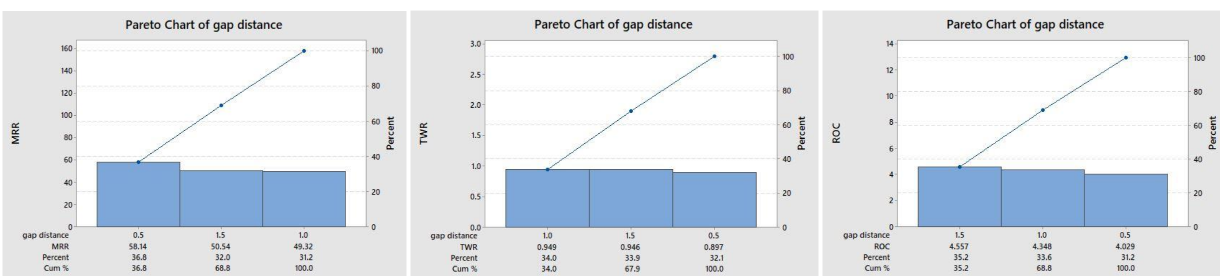

Fig. 3. Effect of gap distance on MRR, TWR and ROC

The analysis by Pareto optimization is carried out to study the relative influence of the discharge gap on the MRR, TWR and ROC of the EDM machined material. From Pareto charts it can be seen that 0.5mm gap distance will give maximum MRR as compared to that of 1mm and 1.5mm. For TWR and ROC, minimum is the best and it can also be achieved with 0.5mm gap distance. 1mm gap distance has maximum TWR and 1.5mm have maximum ROC which provide negative impact on the overall efficiency of the machining process. Therefore 0.5mm gap distance is the optimum gap which can be further used for controlling the constant gap with linear actuator. The graph shows the contribution factors of the parameter and for 0.5mm gap distance, maximum MRR will be at voltage of 45V, Frequency of 6KHz and Duty Factor of 70% respectively.

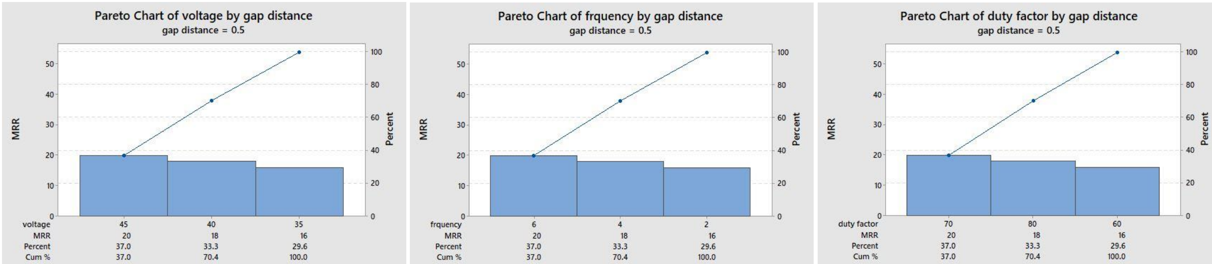

Fig. 4. Pareto chart with MRR of O.5mm gap distance

a b c

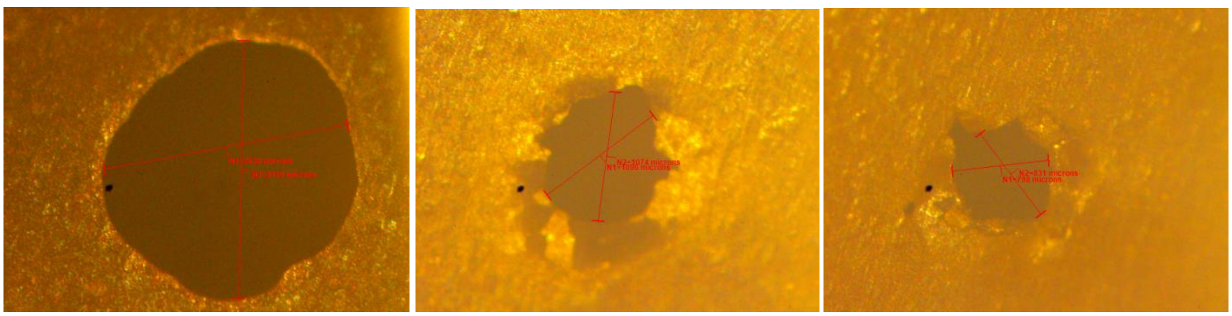

Fig. 5. Microscopic through hole images of different gap distance: (a)-0.5mm, (b)-1mm, (c)-1.5mm

5. Conclusion

The micro-EDM machining in small holes had been investigated. From this experiment it is intuited that, gap distance have major influence for a successful outcome. The result was investigated in terms of MRR, TWR and ROC. From the results it is clear that 0.5mm gap distance will provide better efficiency than other two gap distances. The smaller gap distance will help to point the spark to a particular point. Hence the spread of spark energy can be minimized and there by a better quality holes can be made with minimum tool wear rate. Maximum MRR is better. But TWR and ROC should be minimum. Choosing this gap distance as a parameter for controlling constant gap between tool and workpiece, throughout the machining process as the workpiece material get eroded will provide a positive outcome. The constant gap can be maintained by programming a linear actuator.

References

[1] Mattia Bellotti, Jun Qian, Dominiek Reynaerts, Enhancement of the micro-EDM process for drilling through-holes

[2] M.Dastagiria, P. Srinivasa Raob, P. Madar Vallic, Optimization of EDM process parameters by using heuristic approach, Materials Today: Proceedings 5 (2018) 27036–27042

[3] Zhaojun Koua, Fuzhu Hana, Machining characteristics and removal mechanisms of moving electric arcs in high-speed EDM milling, Journal of Manufacturing Processes 32(2018) 676-684

[4] Nikalje AM, Kumar A, Srinadh KVS. Influence of parameters and optimization of EDM performance measures on MDN 300 steel using Taguchi method. J Adv Manuf Technology 2013;69(1–4):41–9.

[5] LiA, ZhaoJ, HouG. Effect of cutting speed on chip formation and wear mechanisms of coated carbide tools

when ultra-high-speed face milling titanium alloy Ti-6Al-4V. Adv Mech Eng 2017;9(7):1–13.

[6] Nirala CK, Saha P. Precise μEDM-drilling using real-time indirect tool wear compensation. J. Mater. Process. Technol. 2017; 240:176-189

[7] I.Puertas and C.J.Luis, A study on the machining parameters optimization of electrical discharge machining, journal of Materials processing Technology Volumes 143-144, pp 521-526, 20 December2003

[8] P.C. Pandey, S.T. Jilani, Experimental investigations into the performance of water as dielectric in EDM, International Journal of Mechanical tool, vol. 24, no. 1, pp. 31-43, 1984.