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Experimental Investigation on Machining Performance using Deionized Water as Dielectric in Die-Sinking EDM

Kamlesh Paswan*, Rachit Ranjan, Shakuntala Hembram, Rajesh Bajaj, Amit Rai Dixit, Amitava Mandol and Alok Kumar Das

Indian school of mines, Dhanbad - 826004, Jharkand, India; kamlesh.gcr@rediffmail.com, rachitranjan25@gmail.com, mailstoshanky@gmail.com, rajeshbajaj@jssaten.ac.in,amitraidixit@gmail.com, amitava03@gmail.com, eralok@yahoo.co.in

Abstract

Objectives: In this paper the process parameters was thoroughly analysed and optimised for Die sink EDM using deionised water as dielectric on Die Steel work piece using Taguchi experimental design and Analysis of variance (ANOVA) as statistical analysis tool. **Methods/Statistical Analysis:** There are many methods for DOE and analysis as well as optimisation. Taguchi method is most suitable for DOE and analysis to investigate the effect of parameters. Optimal value obtained from Taguchi is further optimized. ANOVA is used to optimize the response and optimized data shows the local optimum value. **Findings:** Response surface roughness examined and optimal combination of input parameters are observed. It is found that TON and peak current have considerable effect on surface roughness whereas gap voltage and duty cycle can be neglected. Response is optimized using analysis of variance (ANOVA). Optimized result shows that low value of peak current and TON produces better surface roughness. **Applications/Improvements:** This paper supports that good surface roughness can be obtained using deionised water on Die steel. As deionised water do not produces toxic fume it can be used frequently without any measure precaution which is needed in oils and kerosene. It is also environment friendly, cheap and easy available in market.

Keywords: ANOVA, Die-Sinking EDM, Die Steel, Deionizer Water, Taguchi DOE

1. Introduction

Electric discharge machining is a process to remove the material from the workpiece by the erosion made by spark travelling from the tool to workpiece through a dielectric medium. It is a non-traditional machining process which uses a formed tool to make the cavity of desired shape. In this process work piece is fully immerged in the dielectric fluid and Potential difference is applied across the work-tool interface which is at some distance apart. Due to potential difference applied the dielectric get ionized and helps in travelling and concentrating the spark in the narrow channel. The dielectric plays an important role in the EDM process by not only insulating the gap between work and tool but also concentrating the discharge into the narrow channel which helps increasing the erosion process[1]. During machining process the creator is produced through the spark by partially vaporizing and melting the work piece in a small zone, the dielectric get vaporized and creates a gas pocket which keeps on expanding and finally explodes, the fluid after explosion of gas pocket rushes towards the gap taking away the molten material and creating a small creator. Since one spark create one crater and there are millions of spark generated within a second so there are millions of crater produce in a second. In this process heat affected zone is very small. Harder and tougher materials are easy to machine in comparison with the ductile materials because in harder material particles are tightly bond which makes the heat to be easily transmit from one particle to another and hence machining is performed easily in the hard materials[2]. The conductivity of workpiece and

* Author for correspondence

tool is the main criterion in electric discharge machining, the Dielectric used should only be conductive during machining in the narrow zone and should be non-poisonous, does not produce foam during machining and should not react with the work piece or tank and also be easy available. Benefit of using EDM is that it can machine very hard and tough conductive materials with high accuracy and is able to produce complex shape. It is extensively used in die making industries. Small diameter holes in carbide or hardened steel can be machined by using tube type electrodes of copper and tungsten using a micro machining attachment. Internal threads and internal helical gears can be cut in hardened materials by using a rotary spindle. Tool used are generally made of highly conducting material such as copper etc. An experiment is carried out to find the parameters which is significant in performing experiment with Deionised water as dielectric.

Earlier many experiments have been done to numerate the controlling parameters for the ameliorate lineament of the machined surface. Literature tells about the different parameters and how they affect the machining operation in die sinking EDM. The Variation in the Flushing rate has very low effects on the machining operation and can be neglected. In[1]have introduce the near mirror finished work-piece by mixing graphite and silicon powder with a particular work piece material like SKH-51[1]. It stated that negative polarity is necessary for minimum surface roughness. Further, In [2]stated that PMEDM clearly improve machining efficiency and surface roughness[2]. Thereafter, by[3] performed experiment to optimize the parameters for EN-31 and has shown that current and TON have maximum influence with lower the value higher the surface roughness[3]. In[4] have performed experiment to determine the effect of silicon powder mixed EDM on AISI D2 die steel and got better metal removal rate and surface quality within the specified limit[4]. In[5] performed experiment for the determination of surface roughness using response surface methodology and has shown that the parameters like current, voltage and pulse ON time has significant effects whereas pulse OFF time is the non-significant parameter[5]. Further it is investigated by[6] performed experiment on EDM Dei sink and analyse data by using Analysis of Variance (ANOVA) and shows that at a particular level of parameter optimal surface roughness can be obtained[6]. Therefore, objective of this experiment is to determine the parameters which affects the surface roughness. Further this paper also investigate the optimum parameters which is suitable to get low surface roughness.

2. Experimental Procedure

There are various parameters in die sinking EDM and to get a desired condition for surface roughness, an experimental setup is developed (Figure 1).

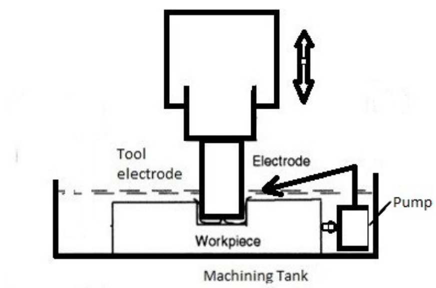


Figure 1. Experimental setup for die sinking EDM.

In this experiment ZNC/35 die sinking EDM machine manufactured by Sparkonix ltd, India was used. Deionised water was used as a dielectric medium instead of conventional dielectric. A small setup was developed in the laboratory to perform the experiment with the minimum amount of deionised water. The size of work-tank was (800mm×500mm×325mm) and is made of Perspex sheet because it has low weight to volume ratio with high strength. Four metallic plates in two pairs are screwed at the bottom of the tank so that it can conduct electricity from one side of the plate to other. A submersible type pump was used for flushing and circulating dielectric in work tank. The operation parameters which may affect the surface roughness are Pick current, Gap voltage, TON and Duty cycle. EN-31 die steel work-piece of geometry ($210\times30\times10mm^3$) was used. Acetone was used to clean machined surface before measuring surface roughness. Physical properties of electrode and chemical composition of workpiece are given below in Table 1.

Signal to noise ratio was Further calculated which shows variation in data. S/N ratio can be calculate in three ways: nominal the best, higher the best and lower the best as shown below:

Table 1. Physical properties of electrode and chemical composition of workpiece

(A)Physical properties of electrode						
Properties of	Melting point	Density	Electrical	Conductivity	Thermal conductivity	Coefficient linear Expansion
Value	1083	8.90	57.59	268-389	16.5×10-6	
Unit	°C	g/cc	ohm/mm	Watt/m-Kelvin	mK^{-1}	
(B) Chemical composition of die steel (AISI D2)						
Element	Carbon	Manganese	Sulfur	Phosphorous	Chromium	Ferrous
Weight	1.07%	0.58%	0.03%	0.04%	1.12%	96.84%

$$HB : {}^{S}\!/\!{}_{N}\, ratio = -10\log_{10}\left[\frac{1}{n}\sum_{i}^{n} = y_{i}^{-2}\right] \quad (1)$$

$$LB : {}^{S}\!/\!{}_{N}\, ratio = -10\log_{10}\left[\frac{1}{n}\sum_{i}^{n} = y_{i}^{-2}\right] \quad (2)$$

$$NB : {}^{S}\!/\!{}_{N}\, ratio = -10\log_{10}\left[\frac{y^{-2}}{s^{2}}\right] \quad (3)$$

Four parameters[7] and 5-levels was taken and experiment was designed by using taguchi[8,9] (L25) as shown in Table 2. Table 3 shows the final results obtained by performing 25 sets of experiment and surface roughness was measured by using surf test (surface roughness measuring equipment).

Table 2. Control parameters and levels

Parameters	L-1	L-2	L-3	L-4	L-5
Pick current- A	1	10	19	28	37
Gap voltage- B	10	30	50	70	90
TON- C	1	9	17	25	33
Duty cycle- D	1	3	5	7	9

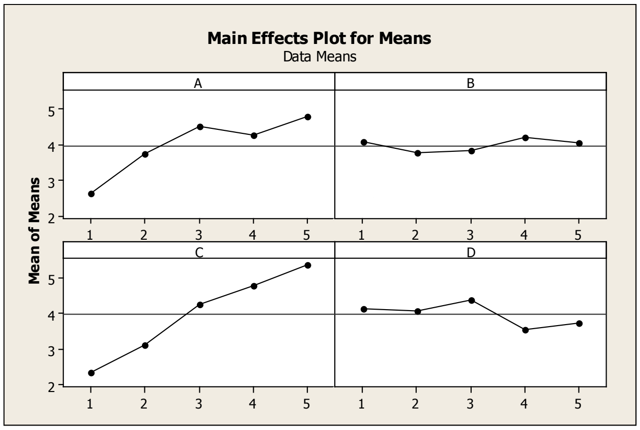
Here A, B, C and D represent Peak current, Gap voltage, T-ON time and Duty cycle respectively.

3. Result and Discussion

Since experiment was designed by[10] method it is an orthogonal array, effect of data calculated and separated from different parameter at different level. The average value of surface roughness and S/N (signal to noise) ratio was estimate from the experimental data. Tabulated data from Table 3 is plot in form of graph to show the deviation of response with input in better manner (Where S/N= signal to noise ratio, S/R= surface roughness). By observing graph 1, 2, 3 and 4 we determine the local optimum value for Peak current, gap voltage, Pulse on time and Duty cycle. From graph, it is clearly observed that Peak current and TON have more impact on surface roughness than the others parameters. Surface is produced with lowest the best type and graph A_1, B_2, C_1 and D_4 shows minimum surface roughness. Variation observed on S/N ratio is also lowest the best type and it also plotted with respect to all variables in graph.

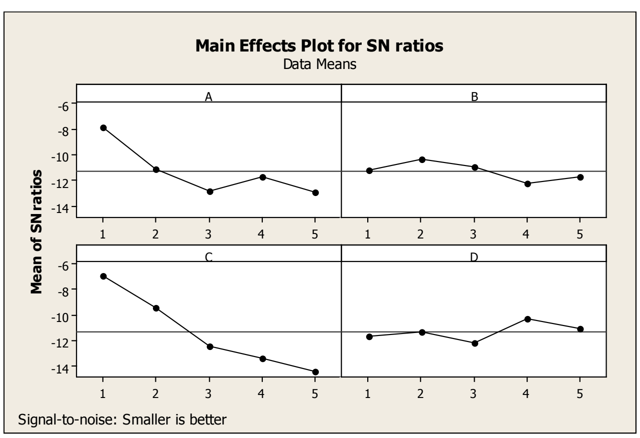
Table 3. Surface roughness values (Raw Data) and S/N ratio Data

Sl.no	Surface roughness (μm)	S/N ratio
1	1.56	-3.86
2	1.66	-4.41
3	2.92	-9.30
4	3.24	-10.21
5	3.64	-11.22
6	2.61	-8.33
7	3.72	-11.41
8	4.43	-12.92
9	5.17	-14.27
10	2.73	-8.71
11	4.99	-13.96
12	4.96	-13.91
13	5.61	-14.98
14	3.77	-11.53
15	3.14	-9.93
16	5.16	-14.23
17	6.36	-16.07
18	1.65	-4.34
19	3.57	-11.06
20	4.48	-13.02
21	5.95	-15.49
22	2.03	6.13
23	4.53	-13.13
24	5.21	-14.34
25	6.14	-15.77



Graph 1. Main effect plot for surface roughness.

Referring to Graph 1, Graph-A it shows that as the peak current increases value of surface roughness upto 19 amp and then has a constant value upto 28 amp. The maximum to minimum value i.e. delta value of surface roughness for peak current has also second highest value of 2.169 showing it as second effective parameters. Graph-B shows the graph between gap voltage and surface roughness, the trend shown is first of decreasing type to the value of 30v and then increasing. Hence, at 30v the value of surface roughness is minimum. Graph-C shows the graph between TON time and surface roughness and is of increasing type, similarly the delta value for this table has highest value making it to be the parameter having highest contribution. Graph-D similarly shows the graph between gap voltage and surface roughness, the trend shows increasing upto the value of 5 and then decreasing.



Graph 2. Main effect plot for S/N ratio.

Referring to Graph2, in Graph-A shows that as the peak current increases. Signal to noise ratio value decreases upto the value 19 amp and then increasing upto 28 amp. The maximum to minimum value of Signal to noise ratio for peak current has also second highest value showing the effectiveness of peak current. Graph-B shows the graph between gap voltage and Signal to noise ratio, the trend shown is first of increasing type to the value of 30v and then decreasing, hence at 30v the value of Signal to noise ratio is minimum Graph-C shows the graph between TON time and Signal to noise ratio and it is of decreasing type, similarly the maximum to minimum value for this table has highest value making it to be the most effective parameter. Graph-D similarly shows the increasing and decreasing trend at alternate level.

Table 4. Analysis of Variance: Surface Roughness

Source	DF	SS	MS	F	Percentage Contribution
A	4	14.58	3.65	2.02	0.29
B	4	0.65	0.16	0.07	0.02
C	4	30.19	7.55	7.37	0.59
D	4	2.18	0.55	0.22	0.04
Model	16	47.6	2.98	7.23	-
Residual	8	3.08	0.38	-	0.06
Total	**24**	**50.68**			

Tables 4 and 5 shows analysis of variance of surface roughness and s/n ratio. From these tables it is clear that TON time and Peak current have more impact on the surface roughness as they have maximum percentage contribution.

Table 5. Analysis of Variance: S/N ratio

Source	DF	SS	MS	F	Percentage Contribution
A	4	88.5	22.13	2.02	0.29
B	4	10.7	2.675	0.07	0.02
C	4	191.5	47.88	7.37	0.59
D	4	10.2	2.55	0.22	0.04
Model	16	300.9	18.81	7.23	-
Residual	8	23.2	2.9	-	0.06
Total	**24**	**324.1**			

3. Confirmation

The Analytical results for mean and S/N ratio shows that A_1, B_2, C_1, D_4 are the most acceptable values for parameters with minimum surface roughness and whose values are shown in Table 6.

Table 6. Optimal levels of parameters

Parameters	Designation	Optimum level
Pick current	A1	1
Gap voltage	B2	30
TON	C1	1
Duty cycle	D4	7

The optimum value of surface roughness is predicted at selected levels of parameters. The estimated mean characteristics can be computed as[11].

μ_{Ra}= average performance + contribution of factors at optimum level

$$= \overline{T} + (A_1 - \overline{T}) + (B_2 - \overline{T}) + (C_1 - \overline{T}) + (D_4 - \overline{T})$$

$$= A_1 + B_2 + C_1 + D_4 - 3\overline{T}$$

$$= .33\mu m$$

Where is average result of surface roughness.

Confirmation test and comparison of the results are given in Table 7.

Table 7. Confirmation test and comparison with result

S.no	Optimum condition Allow (μm)	Predicted S/R(μm)	Experimental S/R(μm)	Maximum
1	A1, B2, C1, D4	0.33	0.861	1.0
2	A1, B2, C1, D4	0.33	0.939	1.0
3	A1, B2, C1, D4	0.33	0.848	1.0

4. Conclusion

This paper contains an experimental investigation and shows the effect of peak current, ton time, gap voltage and duty cycle on surface roughness when using EN-31 Die steel as workpiece and copper as electrode on EDM Die-sink. In order to judge closeness of the predicted value at 95% confidence interval can be statistically calculated as

$$CI = \sqrt{\frac{F(1, n_2, \alpha) \times V_e}{N_e}} \quad (4)$$

$$= 0.67$$

Where CI is confidence interval at 95%, $F(1,n_{2,}\alpha)$ is F value from F table at required confidence level, error of variance is $V_{e,}$= 0.38,n_2 DOF of error = 8, and N_e is effective number.

Here, $Ne = \frac{N}{1+V}$

$= 4.411$

Where N = Total no. of trials and V is total degree of freedom of all factors.

Maximum surface will be allowed is 1.0μm at optimum level of parameters under 95% confidence interval. The result shows that Ton and peak current have maximum effect on surface roughness. Gap voltage and duty cycle are amongst least effective parameters. It is observed from the result that minimum surface roughness obtained at Peak current 1amp, Gap voltage 10v, TON 1 and Duty cycle 70%.

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