

Genetic algorithm approach for optimizing surface roughness of Near dry EDM

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Abstract. In this paper, genetic algorithm (GA) approach is used in order to optimize the surface roughness (Ra) of near dry EDM (ND-EDM) surfaces. Taguchi orthogonal array of L_{27} is used as design of experiment for the five process parameters viz. pulse on time, duty factor, discharge current, gap voltage and tool rotating speed. ANOVA test was conducted and found that pulse on time was the most significant process parameters with 53.38% of contribution followed by duty factor and discharge current with 20.68% and 20.87% of contribution respectively. A regression mathematical model was developed and determined the relationship between the process parameters and surface roughness. GA approach was employed to optimize the process parameter. Then, a validation test was performed and confirmed the optimal process parameters values.

1. Introduction

Electrical discharge machine (EDM) is one of the oldest non-traditional machine process which was first introduced in 1940s [1]. EDM is mainly used in the field of die & mould, medical instrument, aerospace [2]. There is no any direct contact between tool and workpiece while machining, so harder material can so easily machine [3]. EDM uses a single liquid phase medium such as kerosene, hydrocarbon oils, distilled water, tap water, etc. as a dielectric medium. EDM is a thermo-electrical process where material is removed within a liquid dielectric medium by a number of distinct localized electrical discharge when a sufficient voltage is applied between the tool and workpiece. The electrical discharge causes thermal energy of 8000-12000⁰C temperature within the gap [4]. The temperature is very high for melting and even vaporizing at the workpiece [5]. However, EDM has limitations such as low MRR, low surface finish, ununiformly of discharge. In order to minimized such limitations, a modified in the dielectric medium by the mist of two phase medium (liquid-gas) medium is used in EDM process known as near dry EDM (ND-EDM). In the year 1989, the feasibility of ND-EDM was first introduced by Tanimura et al. [6]. Later in the year 2007, Kao et al. [7] conducted a meaningful ND-EDM research on mirror-like surface finish. At lower discharge energy, it has good stability in machining. ND-EDM has better surface finish than conventional EDM [8].



This paper mainly discussed on the important of process parameter of ND-EDM on the surface finish of ND-EDMed surfaces at lower energy level. A Taguchi design of experiment is used and analyzed the significant process parameters. A regression model is established and relate the surface roughness to the process parameters. Finally, Genetic algorithm is approached to determine the optimal process parameters on the surface roughness.

2. Experimental details

2.1. Experimental setup and measurement

An EDM machine manufactured by SAVITA Machine Tool Pvt. Ltd. is used for conducting the experiment and shown in Figure 1. MQL device manufactured by Dropsa is used to fulfill the requirement of the two-phase dielectric medium of ND-EDM. In MQL system, liquid dielectric medium is mixed with the compressed air and formed the near-dry two-phase dielectric medium then, supplied in between the gap of tool and workpiece. Schematic working diagram of ND-EDM is shown in Figure 2. Compressed air is mixed with dielectric liquid at the MQL system and the flow of the air from the solenoid valve is controlled by the MQL flow synchronizer. Thus, a two-phase near-dry dielectric medium is formed and it is supplied in between the gap of tool and workpiece. EN-8 steel is used as a workpiece and a copper tool of diameter 10 mm with a hole of 2 mm diameter is used as a tool. Mitutoyo Sutronic S-128 is used to measure the value of surface roughness, Ra.



Figure 1. EDM Machine

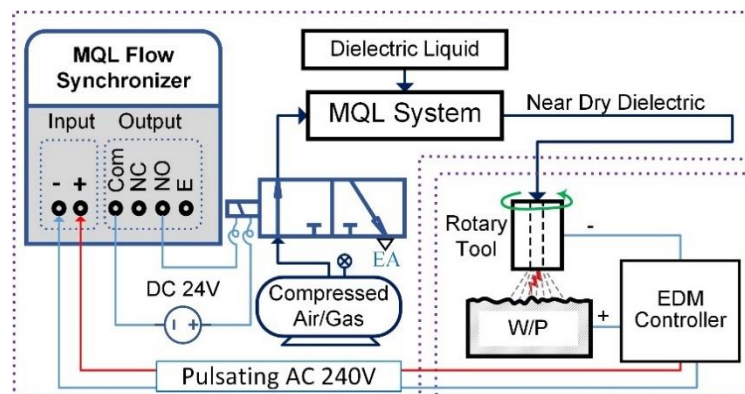


Figure 2. Schematic working diagram of ND-EDM

2.2. Experimental procedure and design

To design the experiment, the process parameters and its levels for lower energy level is selected from the literature reviews and pilot test. Five process parameters namely, Pulse On time, Pulse Off Time, Discharge Current, Tool Rotating speed and Gap Voltage is selected with three levels each depicted in Table 1. A Taguchi orthogonal array of L_{27} is chosen to design the experiment. The experiment is carried out and measured the values of surface roughness. Analysis of Variance (ANOVA) analysis is used to find the significant process parameters on the surface roughness. A Genetic algorithm (GA) approach is used to optimize the process parameters of the surface roughness. A confirmation test is conducted to validated the experiment.

Table 1. ND-EDM process parameters and levels

Process Parameters	Units	Symbol	Level 1	Level 2	Level 3
A: Pulse On Time	μs	Ton	10	30	50
B: Duty Factor	%	DF	70	80	90
C: Discharge Current	A	A	2	5	8
D: Gap Voltage	V	V	45	50	55
E: Tool Rotational Speed	Rpm	N	200	600	1000

3. Results and analysis

The experiment is conducted on Taguchi L_{27} OA. The surface roughness values are measured and depicted in Table 2. The mean response of Ra is estimated and it is depicted in Table 3.

Table 2. L_{27} OA response table

Run	A	B	C	D	E	Ra (μm)	S/N ratio (dB)
1	1	1	1	1	1	3.6	-11.1261
2	1	1	1	1	2	3.3	-10.3703
3	1	1	1	1	3	2.7	-8.6273
4	1	2	2	2	1	4.9	-13.8039
5	1	2	2	2	2	3.8	-11.5957
6	1	2	2	2	3	3.6	-11.1261
7	1	3	3	3	1	5.1	-14.1514
8	1	3	3	3	2	5.2	-14.3201
9	1	3	3	3	3	6.6	-16.3909
10	2	1	2	3	1	4.3	-12.6694
11	2	1	2	3	2	5.2	-14.3201
12	2	1	2	3	3	4.9	-13.8039
13	2	2	3	1	1	7.4	-17.3846
14	2	2	3	1	2	6.7	-16.5215
15	2	2	3	1	3	5.7	-15.1175
16	2	3	1	2	1	5.3	-14.4855
17	2	3	1	2	2	6.2	-15.8478
18	2	3	1	2	3	6.4	-16.1236
19	3	1	3	2	1	7.4	-17.3846
20	3	1	3	2	2	6.9	-16.7770
21	3	1	3	2	3	5.8	-15.2686
22	3	2	1	3	1	6.4	-16.1236
23	3	2	1	3	2	5.6	-14.9638
24	3	2	1	3	3	5.1	-14.1514
25	3	3	2	1	1	7.8	-17.8419
26	3	3	2	1	2	7.2	-17.1466
27	3	3	2	1	3	6.3	-15.9868

It is observed that the optimal level of process parameters is A1B1C1D3E3. ANOVA test is conducted on surface roughness at 95% confidence level and the result is shown in Table 4. The Mean effective plot of Ra is shown in Figure 3. It is found that the pulse on time is the most significant process parameters ($P=0.000<0.05$) with 52.77% of contribution, followed by discharge current ($P=0.01<0.05$) with 20.83% of contribution and duty factor ($P=0.01<0.05$) with 20.81% of contribution. Surface roughness increased with the increase of the pulse on time, discharge current and duty factor. However, surface roughness decreased with the increase of tool rotating speed and slight decreased in Ra with increase of gap voltage.

Table 3. Mean response table of Ra

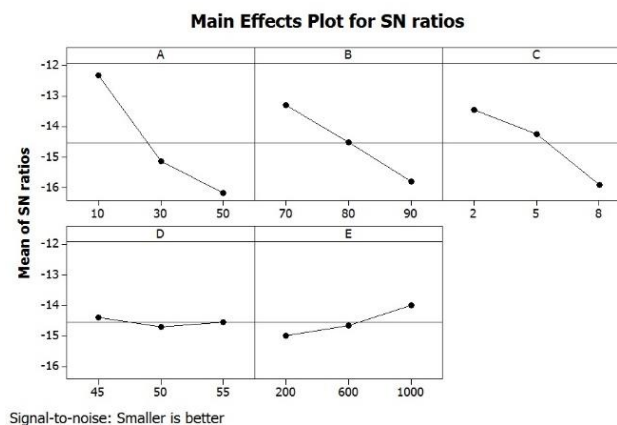
Level	A	B	C	D	E
1	4.311	4.900	4.956	5.633	5.800
2	5.789	5.467	5.333	5.589	5.567
3	6.5	6.233	6.311	5.378	5.233
Delta	2.189	1.333	1.356	0.256	0.567

Table 4. ANOVA result of ND-EDM surface roughness

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% of Contribution
A	2	69.112	69.1118	34.5559	30.41	0.000	53.38
B	2	26.782	26.7818	13.3909	11.79	0.001	20.68
C	2	27.026	27.0257	13.5129	11.89	0.001	20.87
D	2	0.302	0.3017	0.1509	0.13	0.877	0.23
E	2	3.983	3.983	1.9915	1.75	0.205	3.08
Residual Error	16	18.18	18.1802	1.1363			1.76
Total	26	145.384					

3.1. Genetic Algorithm Analysis

Genetic algorithm (GA) is an adaptive search algorithm on the idea of evolutionary genetics. Genetic algorithm solves the problem by simulating the survival of the fittest functions of individuals for successive generation. Here, the fitness function is to minimize the surface roughness, Ra. The fitness function is derived from regression model. Regression model determine the relationship between the process parameters and the response.

**Figure 3.** Mean Effect plot SN ratio of surface roughness

An empirical regression model is chosen and it is given as follow.

$$Y = a + bx_1 + cx_2 + dx_3 + ex_4 + fx_5 \quad (1)$$

Where, Y is the response, R_a ; x_i is the process parameters and ' a, b, c, d, e and f ' are the coefficient.

The regression model is developed using the Minitab software and shown as below.

$$Ra = -1.09444 + 0.05528 \times A + 0.067778 \times B + 0.22963 \times C - 0.023333 \times D - 0.00074 \times E \quad (2)$$

Then, the genetic algorithm search is carried out for the above function as fitness (objective) function bounded by following constraint.

$$\begin{aligned} 10 &\leq Ton \leq 50 \\ 70 &\leq DF \leq 90 \\ 2 &\leq A \leq 8 \\ 45 &\leq V \leq 55 \\ 200 &\leq N \leq 1000 \end{aligned} \quad (3)$$

MATLAB GA toolbox is used to find the optimal process parameters and its levels. The optimal GA fitness values of R_a is shown in Figure 4. The optimal value of 2.68687 μm of R_a is predicted by the GA approach with the optimal process parameters level as $A_1B_1C_1D_3E_3$. A validation test is conducted and depicted in the Table 5.

Table 5. Validation test

	Initial Machining Parameters	Optimal machining parameters	
		Prediction	Experiment
Setting level	$A_1B_1C_1D_1E_3$	$A_1B_1C_1D_3E_3$	$A_1B_1C_1D_3E_3$
R_a (μm)	2.7	2.68687	2.6
Improvement in surface finish = 3.34%			

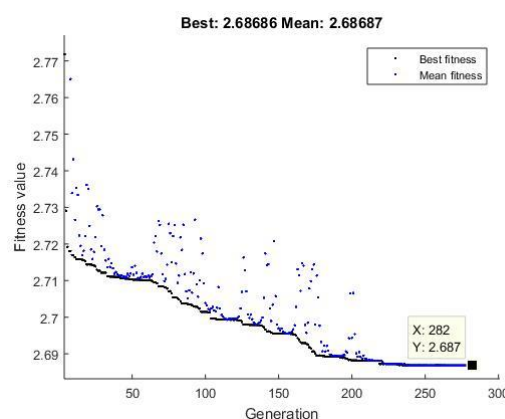


Figure 4. GA fitness values of R_a

4. Conclusion

An experiment on ND-EDM has been carried out using Taguchi L27 OA. The significant process parameter of ND-EDM on the surface finish of ND-EDMed surfaces at lower energy level is determine and found that pulse on time has the most significant process parameters with 53.38% of

contribution followed by duty factor and discharge current with 20.68% and 20.87% of contribution respectively. GA approach has significant search process to determine the optimal process parameter.

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