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Enhancement of Surface Finish of Shape Memory Alloy Using Electrical Discharge Machine

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ABSTRACT

Electro discharge machine is basically used to machine complex profile or hard material which cannot be machine or difficult to machine using traditional machines. Shape memory alloys have super elastic characteristic, so it is very difficult to machine by traditional machines. In this study, themain aim is to enhancement of surface finish of shape memory alloy using Electro discharge machine. For this experiment conducted and results are analyses using statistical analysis methods such as Taguchi method. For experimentation four factors are selected such as gap voltage, discharge current, pulse on time, and pulse off time and analyses response such as surface roughness. For analysis L_9Taguchi orthogonal array used. Finally from statistical technique optimum process parameters are calculated and validate with experimentally.

Keywords- Electro Discharge Machine (EDM), Shape memory alloy, Taguchi, Surface roughness (SR)

INTRODUCTION

EDM is most metal removal process in Nonconventional machining process. Due to its thermal property it has used in manufacturing components of different fields such as automobile, surgical, aerospace field. In EDM machining process, the tool does not make contact with workpiece so it reduces tool breakage or failure of tool, vibration and chatter [9].

EDM is used for machine hard materials. The material which are electrically conductive those materials machine by EDM. The process parameters of EDM plays very important role in machining. While wrong selection of these parameters will effect on breakage of tool, bad quality of surface finish also increase the metal removing rate [4].

EDM is electro thermal process in which electrical energy is used to produce spark. In EDM tool is mounted on ram and workpiece mounted on table. Both tool and workpiece connected to power supply. Tool connected to negative terminal and workpiece connected to positive terminal of power supply. Both tool and workpiece immersed in dielectric fluid [10].

Mr Daniela Tarniţa et al. (2009) [3] studied about properties of shape memory alloy and applications of shape memory alloy in medical field. They mentioned shape memory alloy used in bio surgical instruments due to its properties,

Saeed Daneshmand et al. (2014) [5] investigated effect of process parameters of EDM on response parameters while machining shape memory alloy. From experiment they concluded that discharge current most influencing parameter on the metal removal rate and surface roughness.

Mr Gupta, Parbin K et al. (2012) [6] presented a review on shape memory alloy, its structure and applications. When shape memory alloy heated, after cooling shape memory alloy regain in its original shape. Shape memory alloy are light in weight. Shape-memory alloys used in different medical applications such as, in surgery in orthopedic, in dental apparatus, endoscopy.

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PROBLEM STATEMENT

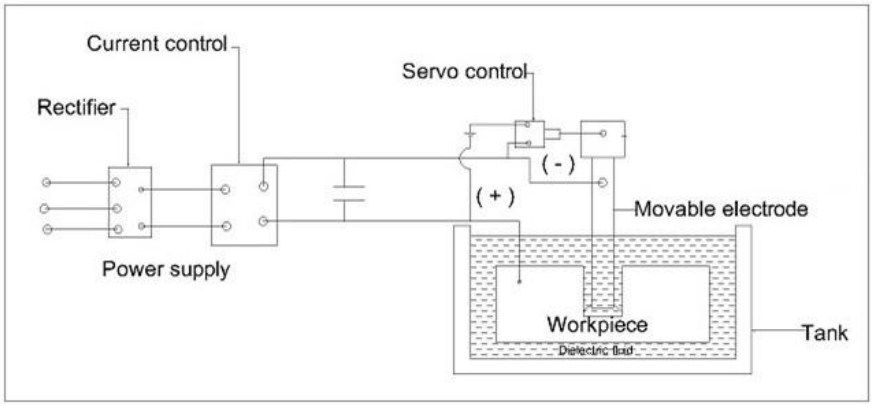

Fig.1. Block Diagram of EDM setup

JaronieMohd Jani et al. (2012) [7], reviews of shape memory alloy research, applications and its opportunities. From review they concluded that many researcher mainly focus on SMA metallurgical properties, but less focus on design and quality of SMA.For that it is require on focus on to minimize cost and minimum failure risk. They suggested for future scope that to develop optimum design model of SMA, which increase effectiveness of SMA quality.
A.P. Markopoulos et al. (2015) [2], studied failure mechanism in SMA and process of deformation.
Then they studied machining of shape memory alloy using conventional and nonconventional machining process. From studied they analyses that shape memory alloy machining with conventional machines were difficult. Also to maintain quality of SMA material is very difficult by conventional machines. While Machining was easy with Nonconventional machines, but some research to be needed to improve quality of SMA.

The aim of this study is to optimization of surface quality of shape memory alloy and investigate effect of process parameter of EDM on shape memory alloy.

EQUIPMENT SETUP:

Fig. 2. Equipment Setup of EDM

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Planning of Experiments

- To develop EDM setup and select input and output parameters based on literature survey.
- Identify the design of experiment methods such as Taguchi method.
- Identify factors and levels based on literature survey.
- Identify standard orthogonal array such as $L_{9.}$
- To develop model of multi objective using Taguchi technique.
- Develop optimal sets of EDM input parameters for improved surface quality.

Selection of Design factors:-

- Application: Bio-Medical- Braces, Dental implants, surgicalinstrument.
- Work piece material – Shape memoryalloy
- Tool Material – Copper
- Process Parameters of EDM –Current, Pulse off time ,Pulse on Time ,Voltage
- Parameters to kept constant – Spark gap, work piece material, toolmaterial
- Responseparameters –MRR, Tool wear, Surfaceroughness

DESIGN OF EXPERIMENT

EDM Specification's

For experimentation Electronica EDM machine was used and shown in fig 2. The electrode or tool was selected as copper, which acts as cathode and workpiece as shape memory alloy (NiTi), acts as a anode.40mm x 50 mm x 15 mm pates of shape memory alloy was selected for machining.Kerosene was used as dielectric fluid. The EDM specifications as Spark gap to be maintain at 10 - 120 µm, Spark frequency as 00 – 500 kHz, Peak voltage across the gap as 30 - 250 V and Maximum material removal rate 5000 mm^3/min.

Selection of an orthogonal array

In this experiment, four factors and three levels were selected for taguchi analysis shown in table 1.The L9 orthogonal array selected and conduct nine experiment with various combination of factors shown in table 2. [1].

Table 1. Initial EDM Parameter

Sr. No.	EDM Parameters		Level		
			1	**2**	**3**
1	A	**Gap Voltage (Volt)**	25	30	100
2	B	**Discharge current (A)**	10	15	20
3	C	**Pulse On Time (µs)**	35	50	100
4	D	**Pulse Off Time(µs)**	5	8	9

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Assigning the independent variable to columns

Table 2. Orthogonal Array of Experimental Combination

Exp. Number	**EDM Parameter Level**			
	Voltage (V)	**Current (A)**	**PulseOn Time(μs)**	**Pulse off Time (μs)**
1	25	10	35	5
2	25	15	50	8
3	25	20	100	9
4	30	10	50	9
5	30	15	100	5
6	30	20	35	8
7	100	10	100	8
8	100	15	35	9
9	100	20	50	5

DATA COLLECTION

While performing experiment using nine combinations of factors the responses were calculated in four repetitions sown in table 3.

Table 3. Data collection Results

Test No.	**A**	**B**	**C**	**D**	**E_1**	**E_2**	**E_3**	**E_4**
T_1	1	1	1	1	5.31	5.38	5.55	5.25
T_2	1	2	2	2	6.25	6.35	6.42	6.30
T_3	1	3	3	3	6.01	6.25	6.30	6.42
T_4	2	1	2	3	6.52	6.55	6.86	6.34
T_5	2	2	3	1	4.62	4.85	4.52	4.66
T_6	2	3	1	2	5.01	5.42	5.30	5.22
T_7	3	1	3	2	6.10	6.18	6.26	6.29
T_8	3	2	1	3	5.12	5.25	5.55	5.20
T_9	3	3	2	1	5.20	5.25	5.15	5.25

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RESULT ANALYSIS:

Result analysis Minitab 17 software used .In above table 4 total four response parameters are selected to detect optimum value of surface finish and calculated mean and S/N ratio.

Table 4. Result Table

Test No.	Repetitions of Responses				Total Test Response	Mean	S/N Ratio
	1st	2nd	3rd	4th			
T_1	5.31	5.38	5.55	5.25	21.49	5.31	-14.5019
T_2	6.25	6.35	6.42	6.30	25.32	6.25	-15.9176
T_3	6.01	6.25	6.30	6.42	24.98	6.01	-15.5775
T_4	6.52	6.55	6.86	6.34	26.27	6.52	-16.285
T_5	4.62	4.85	4.52	4.66	18.65	4.62	-13.2928
T_6	5.01	5.42	5.30	5.22	20.95	5.01	-13.9968
T_7	6.10	6.18	6.26	6.29	24.83	6.1	-15.7066
T_8	5.12	5.25	5.55	5.20	21.12	5.12	-14.1854
T_9	5.20	5.25	5.15	5.25	20.85	5.2	-14.3201

Signal to Noise ratio analysis-

The S/N ratio calculated using experimental readings and analysis perform based on data. Using below formula optimum parameters were selected. [1]
For S/N ratio Smaller is better is calculated from following equation.

$$\text{S/N Ratio} = -10\log_{10}\left(\frac{1}{n}\sum y_i^{\,2}\right)$$

Table 5. To calculate individual factors Mean Change and S/N Ratio

Factors	Result obtained	Mean Change	S/N Ratio
A_1	71.79	5.9825	15.51
A_2	68.44	5.7033	14.70
A_3	66.8	5.5666	14.88
B_1	78.65	6.5543	14.55
B_2	67.98	5.6655	15.76
B_3	78.65	6.5544	15.98
C_1	69.18	5.7655	14.87
C_2	70.37	5.8644	16.87
C_3	69.17	5.7643	15.54
D_1	78.52	6.5435	14.98
D_2	79.85	6.6543	15.98
D_3	81.30	6.7754	16.96

From the result S/N ratio and mean change are plotted.

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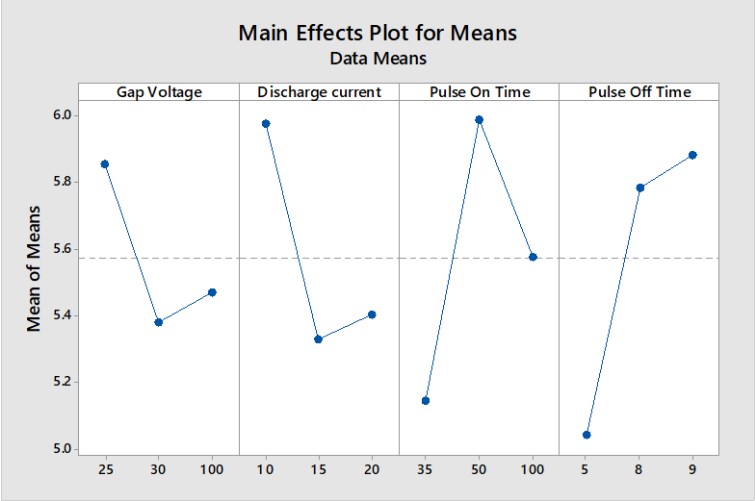

Fig.3.Graph of mean

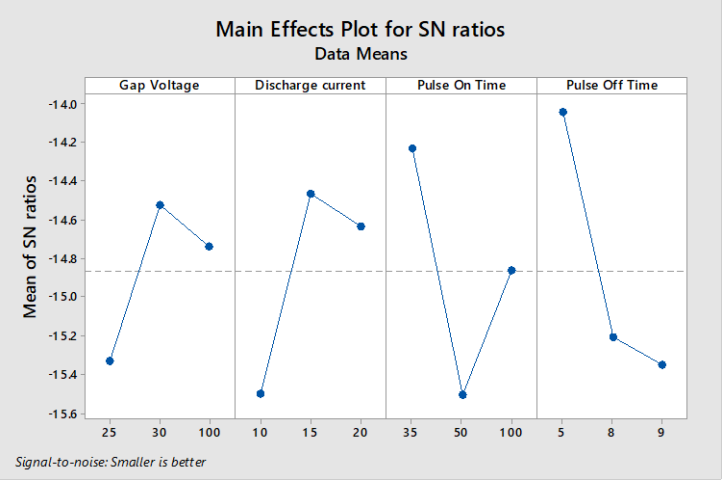

Fig 4. Graph of S/N ratio

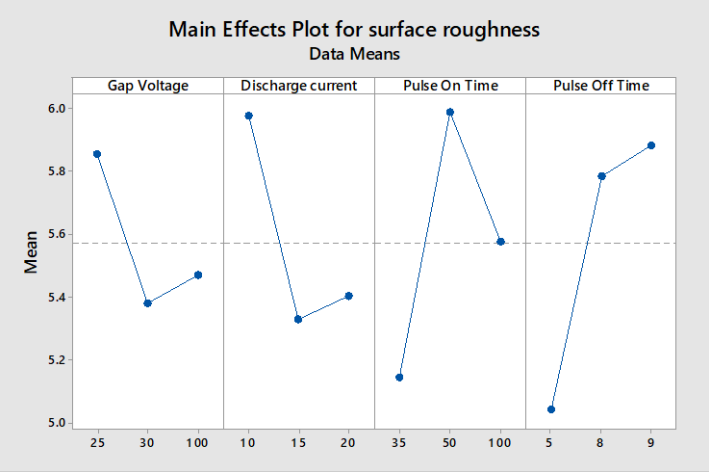

Fig.5.. Graph of Surface roughness

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When pulse current increases then it increase spark and increases discharge current which affect the surface roughness and surface roughness increases.

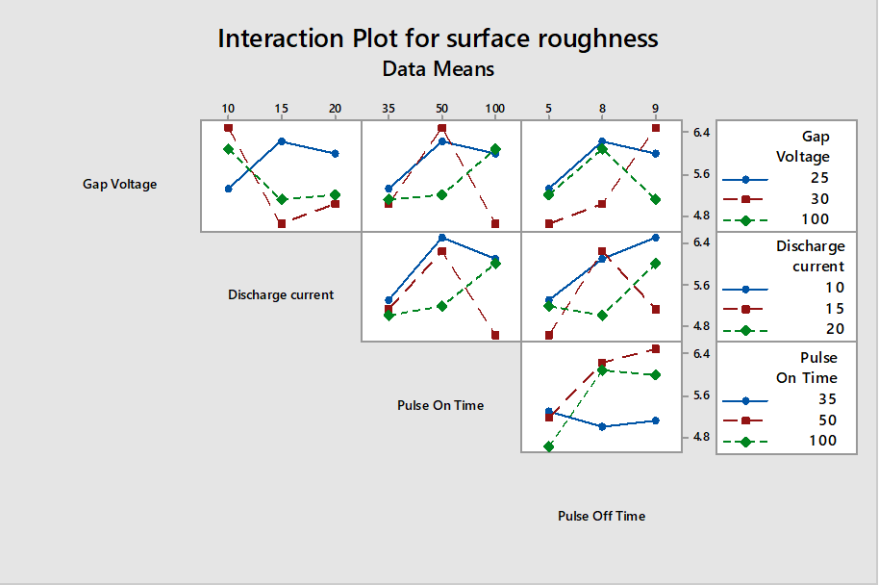

Fig.6. Graph of intraction plot for Surface roughness

From the interaction plot it states that all four parameters were more important for control the response parametes.They dependent with each other. The most effective parameter is dischage current which more affect on quality of suface finish.

FULL FACTORIAL EXPERIMENTAL DATA:-

Full factorial predicted responses were calculated using Minitab software. There were 4 factors and three level in this experiment, so 3*3*3*3 total 81 test samples were predicted and from that the optimum response value and combinations of factors was predicted shown in table 6.

Table 6. Full factorial Experimental Result Table

Test No	A	B	C	D	E
1	1	1	1	1	5.31
2	1	1	1	2	6.25
3	1	1	1	3	6.01
4	1	1	2	1	6.52
5	1	1	2	2	4.62
6	1	1	2	3	5.01
7	1	1	3	1	6.1
8	1	1	3	2	5.12
9	1	1	3	3	5.2
10	1	2	1	1	5.8
11	1	2	1	2	6.6
12	1	2	1	3	6.5
13	1	2	2	1	6.8
14	1	2	2	2	7.4

Test No	A	B	C	D	E
42	2	2	2	3	5.8
43	2	2	3	1	5.2
44	2	2	3	2	6.5
45	2	2	3	3	6.8
46	2	3	1	1	7.4
47	2	3	1	2	4.8
48	2	3	1	3	8.5
49	2	3	2	1	6.8
50	2	3	2	2	7.4
51	2	3	2	3	8.4
52	2	3	3	1	8.5
53	2	3	3	2	7.5
54	2	3	3	3	5.8
55	3	1	1	1	7.4

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15	1	2	2	3	7.2
16	1	2	3	1	6.6
17	1	2	3	2	5.8
18	1	2	3	3	6.9
19	1	3	1	1	6.8
20	1	3	1	2	7.4
21	1	3	1	3	8.5
22	1	3	2	1	6.8
23	1	3	2	2	7.4
24	1	3	2	3	8.4
25	1	3	3	1	8.5
26	1	3	3	2	7.5
27	1	3	3	3	5.8
28	2	1	1	1	5.6
29	2	1	1	2	6.9
30	2	1	1	3	7.4
31	2	1	2	1	8.5
32	2	1	2	2	6.8
33	2	1	2	3	8.5
34	2	1	3	1	7.5
35	2	1	3	2	5.8
36	2	1	3	3	5.6
37	2	2	1	1	4.1
38	2	2	1	2	7.4
39	2	2	1	3	6.9
40	2	2	2	1	7.4
41	2	2	2	2	8.5
56	3	1	1	2	8.5
57	3	1	1	3	6.8
58	3	1	2	1	8.5
59	3	1	2	2	7.5
60	3	1	2	3	5.8
61	3	1	3	1	5.6
62	3	1	3	2	4.7
63	3	1	3	3	7.4
64	3	2	1	1	6.9
65	3	2	1	2	7.4
66	3	2	1	3	5.1
67	3	2	2	1	5.8
68	3	2	2	2	5.6
69	3	2	2	3	6.9
70	3	2	3	1	7.4
71	3	2	3	2	6.9
72	3	2	3	3	7.4
73	3	3	1	1	8.5
74	3	3	1	2	6.9
75	3	3	1	3	7.4
76	3	3	2	1	5.2
77	3	3	2	2	6.8
78	3	3	2	3	7.4
79	3	3	3	1	8.4
80	3	3	3	2	8.5
81	3	3	3	3	7.5

VERIFICATION RUN:

Table 6 shows test 37, optimum value of surface finish i.e. the predicted value of the surface finish is 4.1 µm.
95% Confidence Interval = 4.1 ± 0.01 µm, 99% Confidence Interval= 4.1 ± 0.0127 µm
For validation conduct verification run using optimum combination $A_2B_2C_1D_1$.
We get $A_1B_2C_3D_3$ (Gap voltage 25V, Discharge current 15A, Pulse on time 50 us, Pulse off time 8 us) the value of surface roughness is 4.256 µm, which is close to predicted value,

CONCLUSION

From this study, the optimum parameters related to the EDM of Shape Memory Alloy optimized to attain a low surface roughness. In this experiments nines sets conducted on shape memory alloy using copper electrode and L9 Taguchi orthogonal array. The input parameters taken such as Duty factor, Pulse on-time (Ton) and Discharge current (or pulse current).
From the experiment and design of experiment, the following conclusions were made;
The optimum parameter and level combination for best Surface Roughness is $A_2B_2C_1D_1$ (Gap Voltage 25V, Discharge Current 15A, Pulse On Time 50 µs, Pulse Off Time 8 us).

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REFERENCE

[1] Dayanand S. Bilgi, Pradeep V. Jadhav, (2014), Int. J. Manufacturing Technology and Management, Vol. 28, Nos. 1/2/3,

[2] JaronieMohd Jani (2014), Martin Leary , Aleksandar Subic , Mark A. Gibson , A review of shape memory alloy research, applications and opportunities, Materials and Design 56 1078–1113

[3] Daniela Tarnita,(2009),Properties and medical applications of shape memory alloys, Romanian journal of morphology and embryology , Revue roumaine de morphologie et embryologie 50(1):15-21

[4] Pradeep V. Jadhav,AbhayA.Sawant,(2017), 2017 International Conference on Nascent Technologies in the Engineering Field (ICNTE-2017)

[5] Saeed Daneshmand1, Ehsan Farahmand Kahrizi1, Ali Akbar LotfiNeyestanak2, and Vahid Monfared3 (2014) Journal of Marine Science and Technology, Vol. 22, No. 4, pp. 506-512

[6] Amit Kumar Gupta, (2019), Studies on shape memory alloy-embedded GFRP composites for improved post-impact damage strength, International Journal of Crashworthiness .Volume 24, 2019 - Issue 4

[7] A.P. Markopoulos, I.S. Pressas and D.E. Manolakos, (2015), A REVIEW ON THE MACHINING OF NICKEL-TITANIUM SHAPE MEMORY ALLOYS, Rev.Adv.Mater. Sci. 42, 28-35

[8] Bilgi, D.S. and Jadhav, P.V. (2010) 'Investigations into enhancement of surface finish using PECM', CPIE, pp.714–719.

[9] K.H. Ho, S.T. Newman, (2003), State of the art electrical discharge machining (EDM), International Journal of Machine Tools & Manufacture 43, 1287–1300.

[10] AzharEqubal,Anoop Kumar Sood,(2014),Electrical Discharge Machining: An Overview on Various Areas of Research.Manufacturing and Industrial Engineering 13(1-2)

[11] Sushil Kumar Choudhary, Dr. R.S Jadoun, (2014), Current Advanced Research Development of Electric Discharge Machining (EDM): A Review, International Journal of Research in Advent Technology, pp. 273-297.

[12] Kauffman, G. B. and Mayo, I. (1997), "The story of nitinol: The serendipitous discovery of the memory metal and its applications," The Chemical Educator, Vol. 2, No. 2, pp. 1-21.

[13] Esmail Abedi1,, Saeed Daneshmand, Ali Akbar LotfiNeyestanak, VahidMonfared , (2014) , Analysis and Modeling of Electro Discharge Machining Input Parameters of Nitinol Shape Memory Alloy by De-ionized Water and Copper Tools, Int. J. Electrochem. Sci., Vol. 9 pp, 2934 – 2943.

[14] Panda, D. K. and Bhoi, R. K(2005), "Artificial neural network prediction of material removal rate in electro discharge machining," Materials and Manufacturing Processes, Vol. 20, No. 4, pp. 645-672

[15] Kumar Sandeep, (2013), Current Research Trends in Electrical Discharge Machining: A Review, Research Journal of Engineering Sciences, , pp. 56-60.