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Optimization Of Response Parameters of Electrical Discharge Machine Using Shape Memory Alloy

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Abstract

In this paper, to study the effect of process parameters of Electro discharge machine on shape memory alloy. Output responses such as Surface Roughness & MRR are to be studied. Manufacturers face problem in selecting input parameters which will give stable output response. For optimization Taguchi's design method selected. This method gives optimum results for individual response variable. The surface roughness and Metal removal rate responses were optimized in this experimentation. The optimum parameter and level combination of Electro discharge machine for best surface roughness were finding from Taguchi technique.

Keywords- Electro discharge machine, shape memory alloy, Surface Roughness, Metal Removal Rate, Taguchi.

1. Introduction:

Nontraditional machining process uses different energy sources to remove the material from workpiece. Electro Discharge Machine is nontraditional in which spark is generated and material removal take place by the use of thermal energy. In EDM workpiece is mounted on table and tool is mounted on arbor. Tool and workpiece both used as conductive medium. Tool connected to positive terminal and workpiece connected to negative terminal of power supply. Kerosine used as dielectric fluid. The di-electric fluid flushes workpiece material when spark is generated. Shape memory alloy used in various field such as automobile, medical fields.

2. Literature Review-

Bansiddhi et al (2008) [6] recent research on NiTi foams for bone replacement, focusing on three specific topics: (i) surface modifications designed to create bio-inert porous NiTi surfaces with low Ni release and corrosion, as well as bioactive surfaces to enhance and accelerate biological activity. The first section is a summary of processing methods and properties of NiTi with pore sizes and fractions suitable for implant applications. The second section covers surface modifications of porous NiTi to create surfaces with low and acceptable Ni release levels, improved corrosion resistance, and bioactive properties. The third section addresses the biocompatibility of porous NiTi (with and without surface treatment), including in vitro and in vivo studies for cytotoxicity, genotoxicity, cell culture, bone apposition, and tissue ingrowth. From review they concluded that the roughness of the pore inner surface may have an impact on bone in growth. From that they conclude that more focus on future on greater emphasis on final pore surface quality, more rapid optimization of porous NiTi for biomedical applications is likely to occur in the near future.

Jaronie Mohd Jani et al. (2012) [7], reviews of shape memory alloy research, applications and its opportunities. From review they concluded that many researchers 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) [8], 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.

3. Problem Statement –

To investigation effect of process parameter of EDM on shape memory alloy.

4. Design of Experiment -

4.1 Experimental Setup

Fig.1.EDM setup

Fig.2..Machined plates (Ni Ti Alloy)

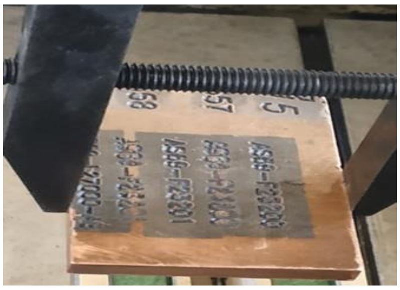

Fig.3..Copper electrode

For experimentation Vinpak EDM machine was used and shown in fig 1. The electrode or tool was selected as copper, which acts as cathode and workpiece as shape memory alloy (NiTi), acts as a anode.20 mm x 25 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

4.2. Selection of an orthogonal array

Table. 1. EDM Parameter

EDM Parameters	Unit	Level-1	Level-2	Level-3
Voltage	V	25	30	100
Current as Discharge	A	10	15	20
Pulse On Time	us	35	50	100
Pulse Off Time	us	5	8	9

4.3. Conducting the experiment

Table.2. Orthogonal Array of Experimental Combination

Test	Gap Voltage	Discharge current	Pulse On Time	Pulse Off Time
1	25	10	35	5
2	25	10	35	8
3	25	10	35	9
4	30	15	50	5
5	30	15	50	8
6	30	15	50	9
7	100	20	100	5
8	100	20	100	8
9	100	20	100	9
10	25	15	100	5
11	25	15	100	8
12	25	15	100	9
13	30	20	35	5
14	30	20	35	8
15	30	20	35	9
16	100	10	50	5
17	100	10	50	8
18	100	10	50	9
19	25	20	50	5
20	25	20	50	8
21	25	20	50	9
22	30	10	100	5
23	30	10	100	8
24	30	10	100	9
25	100	15	35	5
26	100	15	35	8
27	100	15	35	9

4.4. Result Analysis: -

For data analysis a computational tool Minitab ™ released 17 is used from the result table 3, four responses are taken for analysis to find out the optimum combination, which can yield into good surface finish of the machined surface using grinding operation. It helps to propose certain recommendations and process parameters, so that a robust grinding operation procedure can be set to achieve highest quality surface finish. According to L_{27} orthogonal array, 27 experiments conducted and results of surface roughness and metal removal rate shown in table 3.

Table 3. Result Table

Test	Gap Voltage	Discharge current	Pulse On Time	Pulse Off Time	Surface roughness	MRR (mm3/ min)
1	25	10	35	5	5.31	7.375
2	25	10	35	8	5.35	6.146
3	25	10	35	9	5.55	6.914
4	30	15	50	5	6.25	6.062
5	30	15	50	8	6.15	6.056
6	30	15	50	9	6.44	6.062
7	100	20	100	5	6.01	6.062
8	100	20	100	8	5.9	7.375
9	100	20	100	9	6.26	7.375
10	25	15	100	5	6.52	6.291
11	25	15	100	8	6.32	5.531

12	25	15	100	9	6.82	4.425
13	30	20	35	5	4.62	7.375
14	30	20	35	8	4.52	8.749
15	30	20	35	9	5.12	7.375
16	100	10	50	5	5.01	7.375
17	100	10	50	8	5.24	7.375
18	100	10	50	9	5.44	6.914
19	25	20	50	5	6.11	6.062
20	25	20	50	8	5.96	7.375
21	25	20	50	9	5.34	6.146
22	30	10	100	5	5.12	6.062
23	30	10	100	8	5.05	7.375
24	30	10	100	9	5.37	5.531
25	100	15	35	5	5.2	7.375
26	100	15	35	8	5.18	7.375
27	100	15	35	9	5.34	7.375

4.5. Signal to Noise Ratio-

Smaller is Better (S/N) Ratio is used when there is no predetermined value for the target, and smaller the value of the characteristic, the better the surface finish of the work piece.

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

S/N Ratio for T_1 to T_{27} calculate using above equation and presented in table 4.

Table 4. S/N Ratio and Mean for Surface Roughness

Test	Gap Voltage	Discharge Current	Pulse On Time	Pulse Off Time	SR	S/N ratio	Mean
1	25	10	35	5	5.31	-14.5019	5.31
2	25	10	35	8	5.35	-14.5671	5.35
3	25	10	35	9	5.55	-14.8859	5.55
4	30	15	50	5	6.25	-15.9176	6.25
5	30	15	50	8	6.15	-15.7775	6.15
6	30	15	50	9	6.44	-16.1777	6.44
7	100	20	100	5	6.01	-15.5775	6.01
8	100	20	100	8	5.9	-15.4170	5.90
9	100	20	100	9	6.26	-15.9315	6.26
10	25	15	100	5	6.52	-16.2850	6.52
11	25	15	100	8	6.32	-16.0143	6.32
12	25	15	100	9	6.82	-16.6757	6.82
13	30	20	35	5	4.62	-13.2928	4.62
14	30	20	35	8	4.52	-13.1028	4.52
15	30	20	35	9	5.12	-14.1854	5.12
16	100	10	50	5	5.01	-13.9968	5.01
17	100	10	50	8	5.24	-14.3866	5.24
18	100	10	50	9	5.44	-14.7120	5.44
19	25	20	50	5	6.11	-15.7208	6.11
20	25	20	50	8	5.96	-15.5049	5.96
21	25	20	50	9	5.34	-14.5508	5.34
22	30	10	100	5	5.12	-14.1854	5.12
23	30	10	100	8	5.05	-14.0658	5.05
24	30	10	100	9	5.37	-14.5995	5.37
25	100	15	35	5	5.2	-14.3201	5.20
26	100	15	35	8	5.18	-14.2866	5.18
27	100	15	35	9	5.34	-14.5508	5.34

From the calculated result of Mean Change and S/N Ratio Mean effect factor such as A_1, A_2, etc. are plotted and shown in figure 4 and figure 5 respectively.

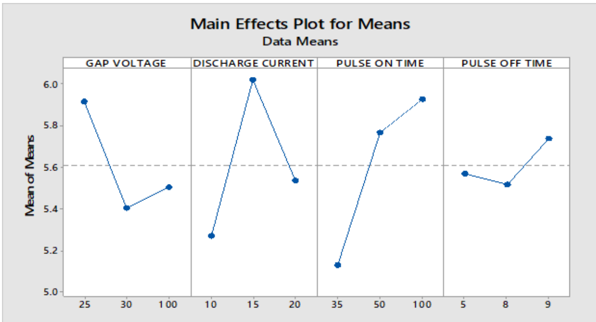

Fig. 4. Main effects plot for Means

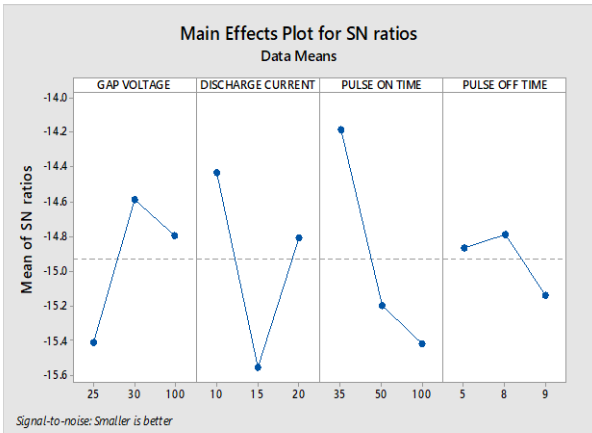

Fig 5. Main effects plot for SN ratios

Table 5. Response table for S/N ratios of SR

Level	Gap Voltage	Discharge current	Pulse On Time	Pulse Off Time
1	-15.41	-14.43	-14.19	-14.87
2	-14.59	-15.56	-15.19	-14.79
3	-14.8	-14.81	-15.42	-15.14
Delta	0.82	1.12	1.23	0.34
Rank	3	2	1	4

Referring to table 5, it is seen that the pulse on time is influencing as main factor for reducing the surface roughness, whereas pulse off time is the least affecting factor.

From the plot of main effect and SN ratio it states that value of S/N ratio decreases as pulse on time increases from low level to high level. Similarly, S/N ratio goes on decreasing when the current increases, that mean SR increases as current increases, the corresponding analysis is shown in fig.6. From the response table for the S/N ratio of SR the optimal machining parameters are selected as gap voltage at level 2, discharge current at level 1, pulse on time at level 1 and pulse off time at level 2.

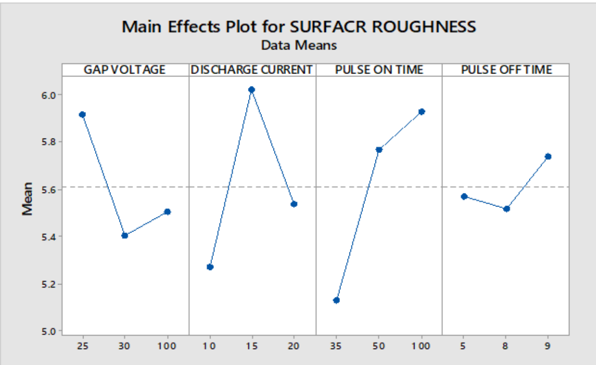

Fig 6. Main effects plot for Surface roughness

From main effects plot for surface roughness, when pulse current increases then it increases spark and increases discharge current which affect the surface roughness quality. From fig 6. Optimum combinations for surface roughness are $A_2B_1C_1D_2$ (Gap voltage 30V, Discharge current 10A, Pulse on time 35 us, Pulse off time 8 us).

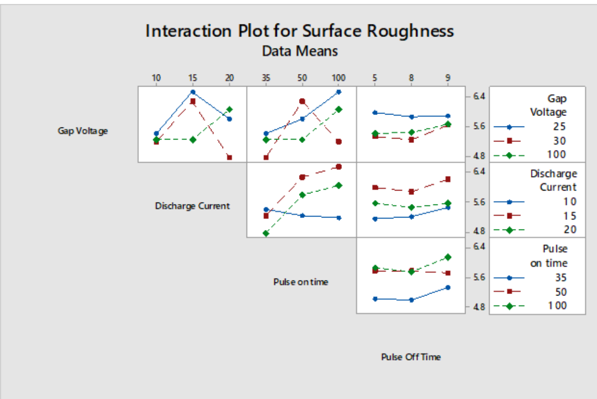

Fig.7. Graph of intraction plot for Surface roughness

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.

4.6. Analysis of Variance (ANNOVA) –

To understand about the significant factor, ANOVA table has been developed.

All these statistical calculations are done in MINI TAB 17.0 software.

Table 6. ANOVA for Surface Roughness

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Voltage	2	1.3681	0.68403	5.94	0.010
Discharge current	2	2.6264	1.31320	11.40	0.001
Pulse on time	2	3.1721	1.5860	13.77	0.000
Pulse off time	2	0.1906	0.09528	0.83	0.453

From Table 6. Checking the F-Value it can be verified that Pulse on time & discharge current are significant parameters affecting Surface roughness.

Regression Equation for surface roughness (Ra)

Regression equation (2) was developed using Minitab 17 software which establishes relationship between surface roughness and other input parameters. Using this equation approximate Ra value can be predicted by entering the input values within the range of EDM.

$$\text{Surface Roughness} = 4.514 - 0.00247\,V + 0.0267\,I + 0.00998\,PO + 0.0286\,PF \qquad (2)$$

4.7. Signal to Noise Ratio MRR-

Table 7. S/N Ratio and Mean for Metal Removal Rate

Gap Voltage	Discharge Current	Pulse On Time	Pulse Off Time	MRR (mm3 /min)	S/N ratio	Mean
25	10	35	5	7.375	-17.3548	7.3746
25	10	35	8	6.146	-15.7711	6.1455
25	10	35	9	6.914	-16.7942	6.9137
30	15	50	5	6.062	-15.6522	6.0619
30	15	50	8	6.056	-15.6441	6.0563
30	15	50	9	6.062	-15.6522	6.0619
100	20	100	5	6.062	-15.6522	6.0619
100	20	100	8	7.375	-17.3548	7.3746
100	20	100	9	7.375	-17.3548	7.3746
25	15	100	5	6.291	-15.9745	6.2911
25	15	100	8	5.531	-14.8561	5.5311

25	15	100	9	4.425	-12.9179	4.4248
30	20	35	5	7.375	-17.3548	7.3746
30	20	35	8	8.749	-18.8395	8.7493
30	20	35	9	7.375	-17.3548	7.3746
100	10	50	5	7.375	-17.3548	7.3746
100	10	50	8	7.375	-17.3548	7.3746
100	10	50	9	6.914	-16.7942	6.9137
25	20	50	5	6.062	-15.6522	6.0619
25	20	50	8	7.375	-17.3548	7.3746
25	20	50	9	6.146	-15.7711	6.1455
30	10	100	5	6.062	-15.6522	6.0619
30	10	100	8	7.375	-17.3548	7.3746
30	10	100	9	5.531	-14.8561	5.531
100	15	35	5	7.375	-17.3548	7.3746
100	15	35	8	7.375	-17.3548	7.3746
100	15	35	9	7.375	-17.3548	7.3746

From the calculated result of Mean Change and S/N Ratio Mean effect factor are plotted and shown in figure 8 and figure 9 respectively.

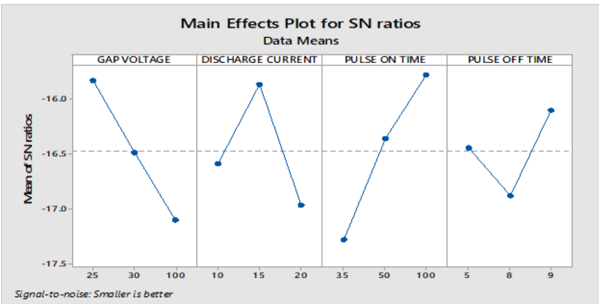

Fig.8. Main effects plot for S/N ratio

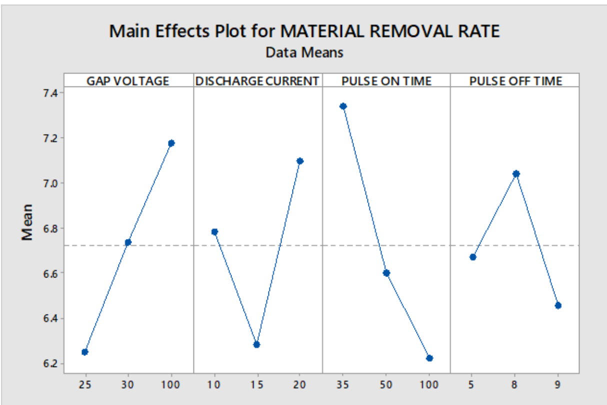

Fig.9. Main effects plot for MRR

4.8. Analysis of Variance (ANNOVA) –

To understand about the significant factor, ANOVA table has been developed.

Table 8. ANOVA for Metal Removal Rate MRR

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Gap Voltage	2	3.863	1.9316	5.25	0.016
Discharge current	2	3.046	1.5232	4.14	0.033
Pulse on time	2	5.783	2.8915	7.85	0.004
Pulse off time	2	1.562	0.7809	2.12	0.149

From Table 8, checking the F-Value it can be verified that Pulse on time & Gap Voltage are significant parameters affecting MRR.

Regression Equation for Metal Removal Rate (MRR)

Regression equation (3) was developed using Minitab 17 software which establishes relationship between MRR and other input parameters. Using this equation approximate MRR value can be predicted by entering the input values within the range of EDM.

MATERIAL REMOVAL RATE = 6.750 + 0.00973 V + 0.0314 I - 0.01473 PO - 0.0127 PF (3)

4. Conclusion -

From this study, the parameters of EDM that optimized by the use of shape memory alloy. In these experiments nine sets conducted on shape memory alloy using copper electrode and L_{27} Taguchi orthogonal array. The process parameters taken such as current, Voltage, Pulse on-time (Ton) and Pulse off time.

From the experiment and design of experiment, the following conclusions were made;

i) The optimum parameter and level combination for best surface roughness from Taguchi is $A_2B_1C_1D_2$(voltage Gap 30 V, Discharge current 10 A, Pulse on time 35 us, Pulse off time 8 us)

ii) From interaction plot it is seen that there is good interaction between all the factors taken as controllable variables in the experiments and they influence each other.

Conflicts of Interest

The authors declare no conflict of interest

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5. References –

[1] Azizul Bin Mohamad, Arshad Noor, Siddiquee, Gulam Abdul Quadir, Zahid A. Khan, V.K. Saini, Optimization of EDM process parameters using Taguchi method, International Conference on Applications and Design in Mechanical Engineering ,2012

[2] E. Aliakbari& H. Baseri, Optimization of machining parameters in rotary EDM process by using the Taguchi method, Int J AdvManufTechnol, , pp. 1041-1053, 2012.

[3] K.M Patel, Pulak M. Pandey. P Vnkateswara Rao, Optimization of process parameters for Multi-performance characteristics in EDM of AL2O3 ceramic composite, Int J AdvManufTechnol,, pp. 1137-1147, 2010

[4] S. Singh, Optimization of machining characteristics in electric discharge machining of 6061Al/Al2O3p/20P composites by grey relational analysis, Int J Adv Manuf Technol, pp. 1191- 1202, 2012.

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

[6] Bansiddhi , T.D. Sargeant, S.I. Stupp, D.C. Dunand, Porous NiTi for bone implants: A review, Acta Biomaterialia ,pp. 773–782, , 2014

[7] Jaronie Mohd Jani, Martin Leary, Aleksandar Subic, Mark A. Gibson, A review of shape memory alloy research, applications and opportunities, Materials and Design 56, pp. 1078–1113, 2014.

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

[9] Xin-Wei Liu, Hui-Juan Shang, Shuo-Gui Xu, Zhi-Wei Wang ,Patellar Shape-Memory Fixator for the Treatmentof Comminuted Fractures of the Inferior Pole of the Patella, Journal of Materials Engineering and Performance Volume 20, pp.623, 2011

[10] Ferdinando Auricchio, Elisa Boatti, Michele Conti, SMA Biomedical Applications, Shape Memory Alloy Engineering, ISBN 978-0-08-099920-3, Elsevier Ltd, 2015.

[11] Shashikant, Apurba Kumar Roy, Effect of optimization of various machine process parameters on surface roughness in EDM for an EN19 material using Surface Response Methodology, Procedia Materials Science , pp. 1702 – 1709, 2014.

[12] M. Janardhan, Multi-response optimization of EDM performance characteristics using response surface methodology and desirability function, ARPN Journal of Engineering and Applied Sciences, pp. 2635- 2649, 2014.

[13] Pradeep V. Jadhav, Abhay A. Sawant, Experimental Investigation on Taper angle of Micro-Electro Discharge machining based on Taguchi Method, 2017 International Conference on Nascent Technologies in the Engineering Field (2017)

[14] AsmaPerveen, M. P. Jahan, An Experimental Study on the Effect of Operating Parameters during the Micro-Electro-Discharge Machining of Ni Based Alloy, International Journal of Materials and Metallurgical Engineering Vol:10, No:11, 2016.

[15] Tyau-Song Huang and Shy-Feng Hsieh, The effect of acetylene as a dielectric on modification of TiNi-based shape memory alloys by dry EDM, Mater. Res., Vol. 30, No. 22, Nov 27, 2015.

[16] Changshui Ga , Zhengxun Liu, A study of ultrasonically aided micro-electrical-discharge machining by the application of workpiece vibration, Journal of Materials Processing Technology 139 ,2003, pp. 226–228.

[17] Murali M. Sundaram, Ganesh B. Pavalarajan, and Kamlakar P. Rajurkar, A Study on Process Parameters of Ultrasonic Assisted Micro EDM Based on Taguchi Method, Journal of Materials Engineering and Performance, 210, 2008, pp. 210–215

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

[19] Pay Jun Liew, Keita Shimada Masayoshi MizutaniJiwang Yan and TsunemotoKuriyagawa, Fabrication of Microstructures on RB-SiC by Ultrasonic cavitation assisted Micro-Electrical Discharge Machining, Int. J. of Automation Technology, 2013, pp. 621-629.

[20] Pradeep kumar, Sunil kumar, Manpreetsingh, Recent Advancement in USM Machining- A Review paper, International Journal of Latest trends in Engineering and Technology, 2015, pp. 225-228.

[21] M. R. Shabgard& H. Alenabi, Ultrasonic Assisted Electrical Discharge Machining of Ti–6Al–4V Alloy, Materials and Manufacturing Processes, 30, 2015, pp. 991–1000.

[22] JiangtaoChe, Tianfeng Zhou, Xijing Zhu, Wenjun Kong, ZhibinWang,XiaodongXie, Experimental study on horizontal ultrasonic electrical discharge machining, Journal of Materials Processing Technology ,231 ,2016, pp. 312–318

[23] Daniel Ghiculescu, NiculaeMarinescu, and Sergiu Nanu, INNOVATIVE SOLUTIONS FOR PERFORMANCES INCREASE AT MICRO- ELECTRICAL DISCHARGE MACHINING AIDED BY ULTRASONICS, Nonconventional Technologies Review, Romania, December, 2014.