International Journal of Management, IT & Engineering
Vol. 7 Issue 8, August 2017,
ISSN: 2249-0558 Impact Factor: 7.119
Journal Homepage: http://www.ijmra.us, Email: editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

MULTI RESPONSE OPTIMIZATION OF PROCESS PARAMETERS FOR MACHINING TITANIUM WITH EDM

M.SrinivasaRao*
Ch.V.S.Parameswara Rao**
SN MalleswaraRao Singu***

Abstract

Electrical Discharge Machine (EDM) is the one nonconventional machining process which is used widely in tooling sector. In EDM, it is necessary to optimize the process parameters like a pulse on time, pulse off- time, discharge current, voltage, for maximization of Material Removal Rate (MRR) and to minimize the tool wear rate (TWR). In this paper, parameter optimization of the electrical discharge machining process to Ti–6Al–4V alloy considering multiple performance characteristics. As per Taguchi L16 design, sixteen experiments have been conducted at different levels of current, T-on, T-off and Voltage. Experimental results of surface roughness, tool wear rate, and metal removal rate were analyzed with Responses Surface Methodology. Interaction effect of process parameters on the responses has been discussed. Multi responses optimization technique was used to optimize process parameters for minimum surface roughness and tool wear rate and maximum metal removal rate. The results were verified through a confirmation experiment. The validation experiments show a reduced electrode wear ratio of 12%, the surface roughness of 19% and improved material removal rate of 10%).

Keywords:
EDM;
ANOVA;
Multi-response optimization;
MRRand TWR;

* **Research Scholar, SV University, Uttar Pradesh**

** **Prof. Mechanical.Engineering**

*** **Post-Doctoral Fellow, Department of Mechanical Engineering, JNTUA College of Engineering, Ananthapuramu, India**

1. Introduction

Electrical Discharge Machine (EDM) now becomes the most important accepted technologies in manufacturing industries since many complex 3D shapes can be machined using a simply shaped tool electrode. EDM is an important 'non-tradition manufacturing method', developed in the late 1940s and has been accepted worldwide as a standard processing manufacture of forming tools to produce plastics moldings, die castings, forging dies and etc. EDM technology is increasingly being used in the tool& die and moulds making industries, for machining of heat-treated tool steels and advanced materials (superalloys, ceramics, and metal matrix composites) requiring high precision, complex shapes, and high surface finish. Traditional machining technique is often based on the material removal using tool material harder than the work material and is unable to machine them economically. An EDM is based on the eroding effect of an electric spark on both the electrodes used. EDM actually is a process of utilizing the removal phenomenon of electrical discharge in the dielectric. Therefore, the electrode plays an important role, which affects the material removal rate and the tool wear rate.

Selvarajan et. al [1] investigated the effect of machining parameters on accurate dimensional & geometrical tolerances. The authors had considered current, T on, T of, dielectric pressure and voltage as parameters and investigated their effects on MRR, TWR, Surface roughness, paper angle & geometric features using the Taguchi L 25 ordinal array. The authors conducted the experiments on Si, Si3N4-TiN material. Bryan et. al [2] conducted experiments on titanium to improve osseointegration capabilities of the metal for orthopedic & dental applications using EDM process by swapping conventional copper electrode with titanium electrode & water as a dielectric. The authors analyzed the physiochemical properties of the surface generated using SEM & EDX. The authors suggested that dual topography surfaces can be created using EDM process for implant applications.

Gangaram et.al [3] conducted experiments on AISIM 2 steel crystalline structure using tungsten – thorium electrode and evaluated MRR, PWR & surface roughness. The authors examined the minimum surface roughness of 1.12 microns was obtained. Soraya Plaza et.al [4] investigated the influence of EDM parameters on MRR electrode wear. Machining time & quality using helically shaped electrode on the Ti6Al4V material use of helically shaped electrode reduced 37% of the machine time.

Pores et.al [5] studied the influence of process parameters on surface roughness MRR & TWR regression techniques are employed to model the outputs. Ali Kandemir et.al [6] conducted experimental work on machining TiNeSiAl composites with EDM. The authors systematically investigated the Ti doping mechanisms by means of density functional theory based formation energy calculations.

Fei wang et.al [7] proposed super high-speed EDM milling and arc machining of Ti6Al4V Titanium alloy rotating pipe graphite electrode is used for experimentation and achieved higher MRR & lower TWR. Tyau et.al [8] made attempts to decrease the martensite transformation temperature of Ti50Ni50 shape memory alloy for its use in biomedical applications by Cr edition. Nitrogen gas is used as dielectric medium and Titanium pipe as an electrode. The authors observed that MRR, TWR & surface roughness increase with an increase in pulse current & duration and they got an inverse relationship with thermal conductivity. J.Y.Kao et.al [9] optimized the process parameters for machining Ti6Al4V alloy considering multiple performing characteristic using Taguchi method and gray relational analysis. The results revealed that lower TWR, higher MRR & better surface roughness.

T. A. El-Taweel [10] investigated the relationship of process parameters in electro-discharge of CK45 steel with tool electrode material such as Al–Cu–Si–TiC composite. The authors considered titanium carbide percent (TiC%), peak current, dielectric flushing pressure, and pulse on-time as input process parameters. The process performances such as material removal rate (MRR) and tool wear rate (TWR) were evaluated. Analysis of variance test had also been carried out to check the adequacy of the developed regression models. Al–Cu–Si–TiC P/M electrodes are found to be more sensitive to peak current and pulse on-time than conventional electrodes.

Wuyi Ming et.al [11] proposed a hybrid intelligent process model, based on the finite-element method (FEM) and Gaussian process regression (GPR), for electrical discharge machining (EDM) process. The authors constructed a model of single-spark EDM process based on FEM method, considering the latent heat, variable heat distribution coefficient of the cathode (fc), and plasma flushing efficiency (PFE), to predict material removal rate (MRR) and surface roughness (Ra). This model was validated using reported analytical and experimental results. Then, a GPR model was proposed to establish a relationship between input process parameters (pulse current, pulse duration, and discharge voltage) and the process responses (MRR and Ra) for EDM process.

A. P. Tiwary et.al [12] studied the influence of various process parameters on material removal rate (MRR), tool wear rate (TWR), overcut (OC), and taper of micro-EDM during machining of Ti–6Al–4V. To perform the experimentation, central composite design (CCD) has been used to design the experiment and response surface methodology (RSM) is utilized to map the relationship between the input process parameters with the resulting process response. It has been observed that RSM models have predicted the process criteria, namely, MRR, TWR, OC, and taper, satisfactorily and can be utilized to predict the response parameters within the range of the parameter selected in the present research investigation.

Horacio T. Sánchez et.al [13] presented an inversion model, based on the least squares theory, which involves establishing the values of the EDM input parameters (peak current level, pulse-on time and pulse-off time) to ensure the simultaneous fulfilment of material removal rate (MRR), electrode wear ratio (EWR) and surface roughness (SR) for AISI 1045 steel with respect to a set of EDM input parameters.

Xiangzhi Wang et.al [14] investigated the influences of dielectric characteristics, namely, electrical conductivity, oxidability, and viscosity on the electrical discharge machining (EDM) of titanium alloy. A new kind of compound dielectric with optimal processing effect was developed by authors based on the identified effects. Comparative experiments on titanium alloy EDM in the compound dielectric, distilled water, and kerosene were performed to analyze the difference in material removal rate (MRR), relative electrode wear ratio (REWR), and surface roughness (SR). The experimental results revealed that titanium alloy EDM in compound dielectric achieved the highest MRR, a lower REWR than that in kerosene, and better SR and fewer micro-cracks than that in distilled water.

Rajneesh Kumar et.al [15] presented a study to investigate the variation of Tool wear, Relative wear with the varying machining parameters (Ton, discharge current and gap voltage) in die sinking EDM. The authors have analyzed the variation of responses with respect to each input machining parameter is presented.

L. Tang & Y. T. Du [16] aims to combine grey relational analysis and Taguchi methods to solve the problem of EDM parameters optimization. From the viewpoint of health and environment, tap water as working fluid has a good working environment, since it does not release harmful gas. The process parameters include discharge current, gap voltage, lifting height, negative polarity and pulse duty factor. The electrode wear ratio (EWR), material removal rate (MRR) and surface roughness (SR) as objective parameters are chosen to evaluate the whole machining effects. Experiments were carried out based on Taguchi L9 orthogonal array and grey relational analysis and then verified the results through a confirmation experiment. Compared the machining parameters A1B1C3D2 with A1B2C2D2 the results showed that using tap water machining Ti–6Al–4V material can obtain high MRR, decrease the machining cost and have no harmful to the operators and the environment.

Arvind Kumar Dixit [17] prepared Titanium aluminide reinforced aluminium based metal matrix nanocomposite was prepared by stir casting route. Experiments were conducted with Cu electrode using L9 orthogonal array based on the Taguchi method. Discharge current (Lv), Pulse on-time (Ton) and Flushing pressure (FP) are selected to calculate Metal removal rate (MRR), Tool wear rate (TWR) and Surface roughness (SR) based on Taguchi's parameter design. Optimum parameter setting is found at Discharge current (Lv) 10 A, Pulse on-time (Ton) 150 μs and Flushing pressure (FP) 1 kg/cm2.

In the present work, experiments have been conducted on EDM machine to identify the effect of process parameters in machining of Titanium. Response surface methodology was used to analyze the experimental results of surface roughness, MRR, and tool wear rate. Multi-response optimization technique is also used to optimize the process parameters.

2. MATERIALS AND EXPERIMENTATION

In the experiments to obtain fine surface finish, die-sinking was conducted using copper electrodes on the surface under different machining conditions. In the EDM, positive electrode polarity resulted in extensive electrode wear compared with material removal rate from the workpiece. On the contrary, negative electrode polarity gives much better surface finish with comparatively higher material removal rate, lower electrode wear and controlled performance. Hence, the experiments were carried out with the electrode as the negative polarity. In the process, the spark always occurs at the closest point between the electrode and the workpiece. Thus if the surface of the electrode facing the workpiece is rough then the machining depth may not be equal to the anticipated depth. As shown in the Fig.1, Experiments were carried out at different levels of current, T-on, T-off and voltages. Workpieces used in this work are shown in the Fig.2.Experimental results of surface roughness, tool wear and MRR are given in Table 1 and 3 for machining Titanium.

Figure 1. *Experimental set up of EDM (Courtesy: PBR VITS-Kavali, A.P., India)*

Figure 2. *Titanium workpieces*

3. RESULTS ANDDISCUSSIONS

3.1 Analysis of responses for TITANIUM

ANOVA was carried out for the Titanium also to identify significant parameter on the surface roughness, tool wear rate, and material removal rate. The ANOVA for the surface roughness was carried out at a confidence level of 95%. Then the responses which are having p-value less than the 0.05 are said to be significant.

From the Table 4, it was observed that the current and voltage have a significant effect on MRR, the voltage has significant effect tool wear rate and current and Ton have a significant effect on the surface roughness.

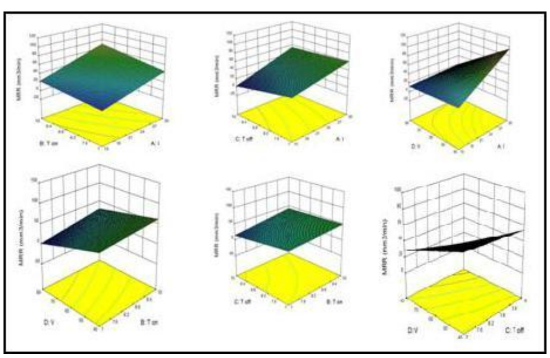
Table 4. ANOVA for Titanium ANOVA for metal removal rate

Source	SS	DF	M S	F- Value	**p-value**
Model	8046.753	10	804.675	10.642	0.0087
A-I	1232.334	1	1232.334	16.298	0.0099
B-T on	228.297	1	228.297	3.019	0.1427
C-T off	144.813	1	144.813	1.915	0.2249
D-V	1656.307	1	1656.307	21.906	0.0054
Residual	378.046	5	75.609		
Cor Total	8424.8	15			
ANOVA for tool wear rate					
Model	0.039	10	3.90E-03	0.89	0.4906
A-I	0.01	1	0.01	2.34	0.1866
B-T on	3.48E-03	1	3.48E-03	0.8	0.4129
C-T off	3.87E-03	1	3.87E-03	0.89	0.3900
D-V	0.012	1	0.012	2.75	0.0158
Residual	0.022	5	4.37E-03		
Cor Total	0.061	15			

ANOVA for surface roughness					
Model	62.64	4	15.66	3.80	0.0355
A-I	18.76	1	18.76	4.55	0.0563
B-T on	40.90	1	40.90	9.92	0.0093
C-T off	0.50	1	0.50	0.12	0.7351
D-V	0.13	1	0.13	0.032	0.8614
Residual	45.36	11	4.12		
Cor Total	108.01	15			

3.2 Interaction effect of process parameters on responses (TITANIUM)

Fig. 3, 4, and 5 shows the interaction effect of process parameters on the responses such as MRR, TWR and surface roughness respectively. From the Fig. 3, it was observed that the current and voltage have a significant effect on the MRR. At low voltage and high current, the MRR is found to be less. From the Fig.4, it was observed that the current, voltage and T-off are having a significant effect on the TWR. The TWR was found to be less at three combinations of parameters such as a combination of low voltage and high current, a combination of low Toff and low current and another combination of lowvoltage and low T-off. From the Figure 5, it can be observed that the current and T-on are found to be strong significant parameters on the surface roughness. The surface roughness was found to be less at fourcombinations of parameters such as a combination of low T-on and low current, a combination of low T-off and high current, a combination of high T-on and low T- off and another combination of low voltage and low T-on.



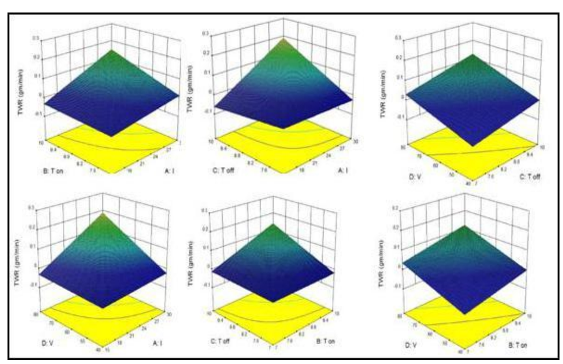


Figure.3*effects of parameters on the MRR* Figure. *4 effects of parameters on the TWR*

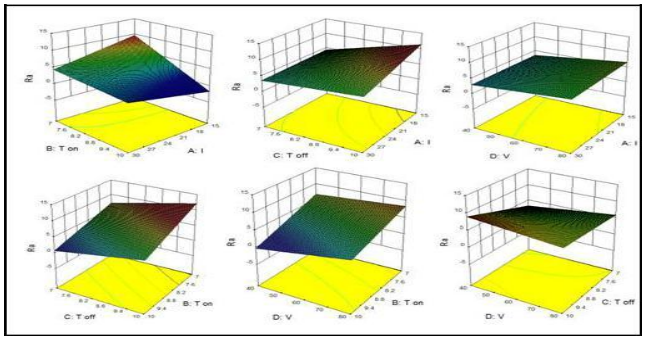


Figure. 5*Interaction effects of parameters on the surface roughness, R_a*

4. MULTI RESPONSE OPTIMIZATION

In the present work, multi-responses optimization was used to optimize process parameters for minimum surface roughness, tool wear rate, and maximum metal removal rate. Fig. 6 show the optimization of process parameters for Titanium. Optimization of process parameters for Titanium was confirmed by desirability value. Composite desirability for TITANIUM was found to be 0.9839. The optimum parameters are tabulated in Table 5.

Table 5. Optimum process parameters

	TITANIUM
Current	30
Ton	8.88
Toff	9.55
Voltage	40
Desirability	0.9839

Figure 6. *Multi response optimization parameters for Titanium*

5. CONCLUSIONS

In the present work, as per Taguchi L16, sixteen experiments have been conducted at different levels of current, T-on, T-off and Voltage on the two metals. Experimental results of surface roughness, tool wear rate, and metal removal rate were analyzed with responses surface methodology. The following conclusions may be drawn from the work.

TITANIUM

- Voltage has a significant effect on MRR, the voltage has significant effect tool wear rate and current and T-on have a significant effect on the surface roughness.
- 30Amp of current, 8.88µs of T-on, 9.55 µs of T-off and 40 V of voltage were found to be optimum process parameter.

References

[1] L. Selvarajan, C. Sathiya Narayanan, R. Jeyapaul, M. Manohar: “Optimization of EDM process parameters in machining Si3N4–TiN conductive ceramic composites to improve form and orientation tolerances” Measurement 92 (2016) 114–120.

[2] Bryan E.J. Lee, SamanthaHo, Gemma Mestres ,MarjamKarlsson Ott, PhilipKoshy, Kathryn Grandfield: “Dual-topography electrical discharge machining of titanium to improve biocompatibility” Surface & Coatings Technology 296 (2016) 149–156.

[3] Gangaram Mandaloi, Subhash Singh, Pradeep Kumar, Kaushik Pal: "Effect on crystalline structure of AISI M2 steel using tungsten–thorium electrode through MRR, EWR, and surface finish" Measurement 90 (2016) 74–84

[4] Soraya Plazaa, Jose A. Sancheza, Endika Pereza, Ruben Gila, Borja Izquierdo,Naiara Ortega,: "Experimental study on micro EDM-drilling of Ti6Al4V using helical electrode: Precision Engineering 38 (2014) 821–827

[5] A. Torres, I. Puertas, C.J. Luis : "Modelling of surface finish, electrode wear and material removal rate in electrical discharge machining of hard-to-machine alloys" Precision Engineering 40 (2015) 33–45

[6] Ali Kandemir, Cem Sevik, Hilmi Yurdakul, Servet Turan: "First-principles investigation of titanium doping into b-SiAlON crystal in TiNeSiAlON composites for EDM applications" Materials Chemistry and Physics 162 (2015) 781-786

[7] Fei Wang, Yonghong Liu∗, Yanzhen Zhang, Zemin Tang, Renjie Ji, Chao Zheng: "Compound machining of titanium alloy by super high-speed EDMmilling and arc machining" Journal of Materials Processing Technology 214 (2014) 531– 538

[8] Tyau-Song Huanga, Shy-Feng Hsieha, Sung-Long Chenb, Ming-Hong Linb, Shih-Fu Oua,∗, Wei-Tse Changa: "Surface modification of TiNi-based shape memory alloys by dry electrical discharge machining" Journal of Materials Processing Technology 221 (2015) 279–284

[9] J. Y. Kao, C. C. Tsao, S. S. Wang, C. Y. Hsu :"Optimization of the EDM parameters on machining Ti–6Al–4V with multiple quality characteristics" Int J Adv Manuf Technol (2010) 47:395–402

[10] T. A. El-Taweel: "Multi-response optimization of EDM with Al–Cu–Si–TiC P/M composite electrode" Int J Adv Manuf Technol (2009) 44:100–113

[11] Wuyi Ming · Guojun Zhang · He Li · Jianwen Guo · Zhen Zhang · Yu Huang · Zhi Chen: "A hybrid process model for EDM based on finite-element method and Gaussian process regression" Int J Adv Manuf Technol (2014) 74:1197–1211

[12] A. P. Tiwary & B. B. Pradhan & B. Bhattacharya: "Study on the influence of micro-EDM process parameters during machining of Ti–6Al–4V super alloy" Int J Adv Manuf Technol (2015) 76:151–160

[13] Horacio T. Sánchez & Manuel Estrems & Félix Faura: "Development of an inversion model for establishing EDM input parameters to satisfy material removal rate, electrode wear ratio and surface roughness" Int J Adv Manuf Technol (2011) 57:189–201

[14] Xiangzhi Wang & Zhidong Liu & Rongyuan Xue & Zongjun Tian & Yinhui Huang: "Research on the influence of dielectric characteristics on the EDM of titanium alloy" Int J Adv Manuf Technol (2014) 72:979–987

[15] Rajneesh Kumar, Om Prakash Sahani, Meghanshu Vashista: "Effect of EDM Process Parameters on Tool Wear" Journal of Basic and Applied Engineering Research, Volume 1, Number 2; October 2014 pp. 53-56

[16] L. Tang & Y. T. Du: "Experimental study on green electrical discharge machining in tap water of Ti–6Al–4V and parameters optimization" Int J Adv Manuf Technol (2014) 70:469–475

[17] Arvind Kumar Dixit: "EDM Process Parameters Optimization for Al-TiO2 Nano Composite" International Journal of Materials Forming and Machining Processes, 2(2), 17-30, July-December 2015 17