Parameter Optimization of EDM Characteristics on Ti-6Al-4V Using Different Electrodes

P.Sumanth *, M. Vaishnav Reddy *, Imran Shaik *, Jagadeeswara Rao Maddu b

a CVR College of Engineering, Hyderabad, Telengana, India
b University College of Engineering, Osmania University, Hyderabad, Telengana, India
* Corresponding author e-mail: jaganmuddu@osmania.ac.in

Abstract. A throughout research has been conducted and enumerated on the process parameters of machining of Ti-6Al-4V alloy in Die sinker EDM. EDM is a well-known UCM measures which is suitable for machining hard and not ease to machine materials of difficult shapes. The method selected for optimization is Taguchi for this paper to examine the characteristics of Ti-6Al-4V alloy and the selected parameter for study is material removal rate. The electrode material selected as brass bronze and copper. The Flushing pressure, current, pulse time-on, pulse time-off and electrodes parameters percentage of contribution and significance effect are analysed with ANOVA. With the observational results, it is evident that current shows significant effect on the response parameter MRR.

Key words: -ANOVA, EDM, MRR, S/N, Ti-6Al-4V, Taguchi,

1. Introduction.

EDM is a one of the most consistent and economical machining processes for titanium and its alloys for past decades. A wide research has been reported in the stream of EDM for machining titanium and its alloys, and several commercially available standard technologies [1]. Thought titanium has advantageous properties like high strength, stiffness at greater temperatures but they are inferred as complex to machine materials by considering the following reasons. 1. poor conductivity, 2. Require large shear forces, 3. High springy when compared to steel, 4. Speed limit in machining of titanium and its alloys ranges around 350 FPT. Hence EDM plays a major role in overcoming difficulties in machining titanium and its alloys. EDM is an electro thermal process suitable in machining conductive materials for manufacturing different automobile and biomedical applications [2]. A large number of electrical sparks was generated between cathode and anode in Electrical discharge machining at a span of seconds. The material removal from work piece takes place with high intensity heat produced by electrical sparks, therefore evident to machine tough materials [4]. As there is no contact between anode and cathode the effects such as mechanical vibrations and stresses are low. In spite of many advantages, instability occurs in the process due to low surface finish, MRR, HAZ and energyconsumption [7]. EDM is depicted in Fig. 1, which narrates mechanisms cut any electrical conductive material irrespective of its hardness. In industrial applications, the Taguchi method has been used to originate the experimental layout to evaluate the outcome of each process parameter on the output characteristic and to depict optimal selection for particular machining parameter [9]. It is crucial that we need to select the proper process parameter to achieve optimum machining performance. The selection of optimal combinations of machining parameters is often challenging as various number of parameters exist and in studying their effects & contributions many researchers showed their interest. Anil Kumar et al (2010), EDM is a modern method of machining used to create geometrically shapes of rigid materials that are very difficult to machine by traditional machining
process are processed. This technique of non-contact machining is continuously proving in manufacturing tools and dies in micro level. In recent years, research has been conducted on emphasising the improved efficiency of machining combined with surface treatments for better surface finish [8]. R. Venkata Rao et al, The primary Emphasis is held on the aspects of Optimisation of different parameters of the modern processes of machining and techniques for Optimisation were involved. The evaluation time and the research consideration considered is from 2006 to 2012. Similar modern processes like electric discharge process considered in this work and hybrid versions of these processes. Considering many processes at a time and thus the work of this analysis could be available at one location, the ready knowledge can be very useful in determining their course for the subsequent researchers from studies [11]. Ankit Jain et al, were carried out the experiments by best choosing I27 orthogonal array drilled Titanium alloy using electric discharge drilling. for experimentatio the input process parameters and output parameters selected discharge current, pulse on time, pulse off time, dielectric pressure and hole circularity, hole taper respectively. The data from the experiments used for the establishment of multi regression using genetic algorithm MATLAB tool. The multi-objective outcome of the genetic algorithm optimisation shows progress in the output parameters [10]. V. S. Nimbalkar, In order to consider the effect of three significant EDM parameters, Taguchi analysis is used namelyPulse on time and discharge current, and difference voltage. In this survey, using Analysis of Variance (ANOVA) and the effect & contribution of process parameters on the responses is studied and contrasted with the mathematical models for validationTi-6Al-4V (Titanium alloy) and Ti-6Al-4V (Titanium alloy) have been studied. Strong Copper and hollow copper electrodes were used as the instrument. Using Taguchi study, the output response is designed using the experimental values obtained [12]. From the observations of previous studies not much focus spent on the effect of parameters and optimization of parameters. Here our study focus on finding optimum parameters, using ANOVA the level of significance of output parameters such as MRR and SR was studied and best combination set of parameters selected using Taguchi L18 design. In order to examine the effects of process parameters Design software Minitab 16 was employed. To determine the significant factors as well as to develop of the EDM response MRR the analysis of variance (ANOVA) were performed.

2. Methods and materials.
The work in this investigation was done on EDM machine CREATER Make. The work starts with selection of material, input and output parameters. Electrode as brass bronze and copper was selected shown in fig 2 and Ti-6Al-4V alloy chosen as the job material. The EDM parameters chose were flushing pressure, current, pulse time-on, pulse time-off and electrodes. Table 1 indicates the design of experiments with parameters and their levels. Table 2 describes the matrix design on full factorial 18 investigations. The output parameter chosen is MRR. Experiments were directed depending on the design of experiments approach. ANOVA technique is used to find out significance level of parameters and their effect on MRR. For each test run, rectangular samples of 20x20x8 mm measurements were utilized for a set of indicated input parameter combinations shown in fig 2. The MRR was measured utilizing the formula.

\[
\text{MRR} = \frac{(\text{Weight before Machining} - \text{Weight after Machining})}{\text{Time of machining}}
\]

Table 1. Selected process parameters and respective levels.

| S. No | Parameters     | Level-1  | Level-2 | Level-3 |
|-------|----------------|----------|---------|---------|
| 1     | Flushing pressure | 0.35     | 0.7     |         |
| 2     | Current         | 10       | 20      | 30      |
| 3     | Pulse on Time   | 200      | 400     | 600     |
| 4     | Pulse off Time  | 40       | 80      | 120     |
| 5     | Electrodes      | Copper   | Bronze  | Brass   |
To analyze the outcomes of test runs and each parameter significance to be assessed with ANOVA for the outcome of MRR. Minitab 16 was utilized to perform the ANOVA test for knowing the importance of parameters. Taguchi shows S/N ratio which became the objective of DOE. these objectives are categorized as larger, smaller and nominal the better. The DOE and the outcome obtained from the experiments were tabulated in table 2. It is observed from the matrix that the set of input parameters combinations Flushing pressure (0.7 Kg/cm2), current (10 amp), pulse time-on (400), pulse time-off (40) and electrode (brass), experiment 13 results maximum MRR.

Table 2. Set of 18 experiments and resulting MRR and S/N Ratio.

| S.No | Flushing pressure | Current | Pulse on Time | Pulse off Time | Electrodes | M.R.R | S/N Ratio |
|------|------------------|---------|---------------|----------------|------------|-------|-----------|
| 1    | 1                | 1       | 1             | 1              | 1          | 1.16479 | 1.32492   |
| 2    | 1                | 2       | 2             | 1              | 2          | 0.96614 | -0.2992   |
| 3    | 1                | 3       | 3             | 1              | 3          | 0.19639 | -14.138   |
| 4    | 1                | 1       | 1             | 2              | 2          | 3.2754  | 10.3053   |
| 5    | 1                | 2       | 2             | 2              | 3          | 0.23928 | -12.422   |
| 6    | 1                | 3       | 3             | 2              | 1          | 0.79233 | -2.0219   |
| 7    | 1                | 1       | 2             | 3              | 1          | 0.62077 | -4.1414   |
| 8    | 1                | 2       | 3             | 3              | 2          | 1.50113 | 3.52836   |
| 9    | 1                | 3       | 1             | 3              | 3          | 1.81242 | 5.16515   |
| 10   | 2                | 1       | 3             | 1              | 3          | 1.41761 | 3.03112   |
| 11   | 2                | 2       | 1             | 1              | 1          | 0.82299 | -1.6921   |
| 12   | 2                | 3       | 2             | 1              | 2          | 0.40406 | -7.871    |
| 13   | 2                | 1       | 2             | 2              | 3          | 3.65237 | 11.2515   |
| 14   | 2                | 2       | 3             | 2              | 1          | 2.47404 | 7.86814   |
| 15   | 2                | 3       | 1             | 2              | 2          | 0.21494 | -13.354   |
| 16   | 2                | 1       | 3             | 3              | 2          | 0.7088  | -2.9895   |
| 17   | 2                | 2       | 1             | 3              | 3          | 0.85779 | -1.3324   |
| 18   | 2                | 3       | 2             | 3              | 1          | 2.06321 | 6.29085   |
3. Results and discussions

Material Removal Rate Analysis. Table 2 exhibits the MRR experimental results with the orthogonal array and its S/N ratio values. ANOVA’s Primary aim is to know the influence of selected parameters. MRR results were calculated by ANOVA and percentage of contribution of each parameter were reported in Table 3. From the table it is evident that current has high influence with percentage 57.98%, other parameters pulse off time, electrodes, flushing pressure and pulse-on-time with 22.44, 11.56, 3.56, 1.74% respectively.

Table 3: Analysis of Variance for SN ratios

| Source          | DF | Seq SS | Adj SS | Adj MS | F    | P    | %   |
|-----------------|----|--------|--------|--------|------|------|-----|
| Flushing pressure | 1  | 10.74  | 10.736 | 10.736 | 0.12 | 0.740 | 3.56 |
| Current         | 2  | 166.65 | 166.650| 83.325 | 0.92 | 0.438 | 57.98|
| Pulse on time   | 2  | 5.02   | 5.022  | 2.511  | 0.03 | 0.973 | 1.74 |
| Pulse off time  | 2  | 64.50  | 64.502 | 32.251 | 0.36 | 0.711 | 22.44|
| Electrodes      | 2  | 33.25  | 33.251 | 16.625 | 0.18 | 0.836 | 11.56|
| Residual Error  | 8  | 7.26   | 7.26   | 3.633  |      |      | 2.53 |
| Total           | 17 | 287.42 |        |        |      |      |     |

Table 4: Response table for Signal to Noise ratio.

| Level | A       | B       | C       | D       | E       |
|-------|---------|---------|---------|---------|---------|
| 1     | -1.41094| 3.13032 | 0.06954 | -3.27400| 1.27140 |
| 2     | 0.13367 | -0.72486| -1.19854| 0.27124 | -1.77994|
| 3     | -4.32136| -0.78691| 1.08684 | -1.40738|
| Delta | 1.54461 | 7.45168 | 1.26809 | 4.36084 | 3.05134 |
| Rank  | 4       | 1       | 5       | 2       | 3       |
4. Conclusions:

EDM of Ti-6Al-4V alloy specimens has an impact of machining process factors on MRR studied analytically. The tests were conducted according to the factorial design of Taguchi L18 to test the impact of factors including flushing pressure, current, pulse time-on, pulse time-off and electrodes are machined. ANOVA has been performed in order to assess the significance of parameters. The following conclusions that emerged based on the test results were reported from the findings. The key significance parameters are current, and pulse-off time with percentage of contributions 57.98 and 22.44% respectively. Flushing pressure (0.7 Kg/cm²), current (10 amp), pulse time-on (400), pulse time-off (40) and electrode (brass), are the optimal conditions for MRR.

References

[1] Gill, S. S., & Singh, J. (2010). Effect of deep cryogenic treatment on machinability of titanium alloy (Ti-6246) in electric discharge drilling. *Materials and Manufacturing Processes*, 25(6), 378–385.

[2] Garg, M. P., Jain, A., & Bhushan, G. (2014). Multi-objective Optimization of Process Parameters in Wire Electric Discharge Machining of Ti-6-2-4-2 Alloy. *Arabian Journal for Science and Engineering*, 39(2), 1465–1476.

[3] Kumar, A., Kumar, V., & Kumar, J. (2014). Microstructure analysis and material transformation of pure titanium and tool wear surface after wire electric discharge machining process. *Machining Science and Technology*, 18(1), 47–77.

[4] Prakash, C., Kansal, H. K., Pabra, B. S., & Puri, S. (2017). Experimental investigations in powder mixed electric discharge machining of Ti–35Nb–7Ta–5Zrβ-titanium alloy. *Materials and Manufacturing Processes*, 32(3), 274–285.

[5] Prasad Arikatla, S., Tamil Mannan, K., & Krishnaiah, A. (2017). Parametric Optimization in Wire Electrical Discharge Machining of Titanium Alloy Using Response Surface Methodology. *Materials Today: Proceedings*, 4(2), 1434–1441.

[6] Oliver Nesa Raj, S., & Prabhu, S. (2017). Modeling and analysis of titanium alloy in wire-cut EDM using grey relation coupled with principle component analysis. *Australian Journal of Mechanical Engineering*, 15(3), 198–209.
[7] Goyal, R., Sngh, S., & Kumar, H. (2018). Performance evaluation of cryogenically assisted electric discharge machining (CEDM) process. *Materials and Manufacturing Processes*, 33(4), 433–443.

[8] Krishna, P. V., Reddy, V. V., & Kumar, B. S. (2017). Experimental Investigation on EDM of Titanium Alloy using Taguchi Method. 5(05), 134–139.

[9] Ram Prasad, A. V. S., Ramji, K., &Kolli, M. (2019). An experimental investigation on machining parameters of titanium alloy using WEDM. *Materials Today: Proceedings*, 18, A12–A16.

[10] Pramanik, A., &Basak, A. K. (2019). Effect of wire electric discharge machining (EDM) parameters on fatigue life of Ti-6Al-4V alloy. *International Journal of Fatigue*, 128(February), 105186.

[11] Rao, R. V., &Kalyankar, V. D. (2014). Optimization of modern machining processes using advanced optimization techniques: A review. *International Journal of Advanced Manufacturing Technology*, 73(5–8), 1159–1188.

[12] Nimbalkar, V. S., &Shete, P. M. T. (2017). Experimental investigation of machining parameters using solid and hollow electrode for EDM of Ti-6Al-4V. *International Research Journal of Engineering and Technology* (IRJET), 04(05).