© 2017 IJSRSET | Volume 3 | Issue 1 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

# Experimental and Numerical Analysis of Metal Removal Rate and Surface Finish on Al- Ti Alloy

**Aitha Shravan*[1], Samatham Madhukar[2], Bootla Akhil[3], Dr. A. A. Sri Rama Krishna[4]**

[1,2,3] Mechanical Department, Vidya Jyothi Institute of Technology, Hyderabad , Telangana , India
[4] Chaitanya Bharathi Institute of Technology, Hyderabad, India

## ABSTRACT

Advancement in technology has led to development of many materials with better qualities in order to develop products of greater value. This has led to a search for better materials to satisfy the ever growing demands of product requirement. One of this material is titanium alloys which is widely used in the aerospace and aircraft industry are due to their ability to maintain their high strength at elevated temperature, and high resistance for corrosion. They are also being used increasingly in chemical process, automotive, biomedical and nuclear industry .[1,2]Titanium and its alloy are considered as important engineering materials for industrial applications because of good strength to weight ratio, superior corrosion resistance and high temperature applicability. They also has outstanding resistance to corrosion in most natural and much industrial process environment. When machining titanium alloy with conventional machines, the tool wear rate progress rapidly. Some type of tool material including cemented carbide, ceramics are highly reactive with titanium alloy at high temperature. As these materials are harder and comparatively have higher strength when compare to other materials therefore conventional machining process are not suitable for machining these hard materials and to get complicated profiles is very difficult hence Non-conventional machining process is suitable to machine these materials, one such process is EDM-(Electric discharge machining).[3] Metal removal rate (MRR), Surface roughness (SR) are the two most important parameters which can be measured and varied using EDM process. The surface roughness of the machined surfaces was measured with surface roughness measuring instrument SURFTRONIC 3+. The present paper deals with machining of metal Al-Ti Alloy .In which MRR modelling has been carried out using axi-symmetric model of MMC during EDM machining.A FEA model of single spark EDM was developed to calculate the temperature distribution. Further, single spark model was extended to multi-discharge machining material removal was calculated by calculating the number of pulses and experiments were conducted using CNC Sinking Electrical Discharge Machine (CHMER Thai van Make) validation of model has been done by comparing experimental results with analytical results and good agreement was found out.

**Keywords :** Electrical Discharge Machine , Titanium Alloy

## I. INTRODUCTION

The evolution of the concept of designing materials for a particular application rather than choosing from available materials paved the way for tremendous development in materials technology, since 1950. In this process several alloys have been developed for various applications. Alloy materials are a result of the continuous attempts to develop new engineering materials with low weight to strength ratios and improved properties. Among them Titanium alloys are metals that contain a mixture ofalloys have very high tensile strengthweight, have extraordinary corrosion resistance.[4,5]It is one of the fastest growing materials used in aerospace applications. The prime rationale for designers to chose titanium in their designs is its relative low massfor a given strength level and its relative resistance to high temperature. It has long been used in aircraft engine front sections and will continue to be used there for the foreseeable future.In fact, due to its properties, titanium alloys are becomingmore prevalent than ever before in structural and landinggear components.One drawback of these alloys is their poor machinability when machined using conventional method which makes the way to unconventional machining .One of this type of machining is EDM( Electric Dischrge Machinign) .In this machining Al-Ti Alloy material has been used as a work piece for present experimentation study, copper material has been used as electrode and kerosene as the dielectric in the EDM process. Various current and voltage alterations have been applied and machining has been done. A model was generated in FEA (using ANSYS software) using QUAD 4 NODE element, PLANE 55 an axis symmetric model has been generated and a part of it has been taken and a refined mesh has been made on it based on convergence criteria and analysis has been performed for the metal rate removal and temperature distribution.[6] Firstly a transient thermal analysis was carried out by using heat flux as the time varying input to estimate the temperature variation and metal removal rate. The nonlinear material properties are fed for the heat transfer solution. After the application of heat flux, node to node distance is found out till the melting temperature of the material and the radius is measured and the metal removal rate is found out and later the predicted results obtained from the model have been verified with the experimental results and very good co-efficient of correlation has been found between predicted and experimental results.

## II. METHODS AND MATERIAL

### A. Numerical Analysis

Plasma channel incident on the work piece surface causes the temperature to rise in the work piece. The distribution of plasma channel can be assumed as uniform disk source or Gaussian heat distribution, for EDM. Gaussian distribution of heat flux is more realistic and accurate than disc heat source. Fig.1 shows the schematic diagram of thermal model with the applied boundary conditions.[7]

The work piece domain is considered to be axisymmetric about z axis. Therefore taking this advantage, analysis is done only for one small half (ABCD) of the work piece. The work piece domain considered for analysis is shown in Fig. It is clearly evident from Fig.1 that the maximum heat input will be at point A. On the top surface, the heat transferred to the work piece is shown by Gaussian heat flux distribution. Heat flux is applied on boundary 1 up to spark radius R, beyond R convection takes place due to dielectric fluids. As 2 & 3 are far from the spark location no heat transfer conditions have been assumed for them. For boundary 4, as it is axis of symmetry the heat transfer is zero.[8]

The flux is calculated by

$$Q(r) = \frac{4.45PVI}{\pi R^2} exp\left\{-4.5\left(\frac{r}{R}\right)^2\right\}$$

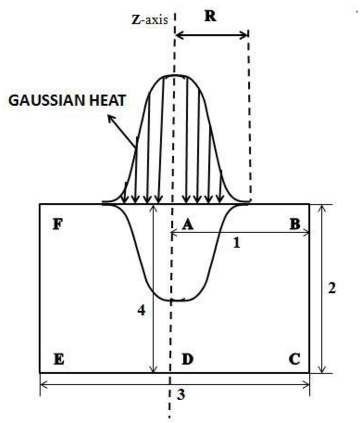


**Figure 1.** Axisymmetric Model for the EDM process Simulation

### B. Modeling Procedure

EDM is a complicated process that required a powerful tool to stimulate the process. In present analysis the simulation has been done on ANSYS. In present analysis a axi- symmetric model of dimension 35μm ~ 30μm been created and element selected for analysis is quad 4 node 55.

Fig.3 shows the temperature distribution, during the spark on time the temperature rises in the work piece and temperature rise is sufficient enough to melt the matrix due to its low melting temperature but the reinforcement remains in solid form due to its very high melting temperature. After the melting of Al-Ti Alloy no binding exists between t, therefore reinforcement evacuates the crater without getting melted. Therefore from the nodal temperature distribution figure thedistance between the nodes is found out and the extreme node is selected till the melting temperature of the material that is Al-Ti Alloy From the Fig.2 it is clear that the shape of molten material is semi sphere. The molten crater can be assumed to be hemispherical in nature with a radius r which forms due to a single spark.

Hence MRR volume for single spark is

$$\mathbf{MRR_{(1)}} = \frac{2}{3}\pi R^3$$

R- Radius of crater is range of temperature more than melting point of the work piece calculated from ansys solved temperature distribution model.[9,10]
For multi spark analysis we need to calcite the NOP- number of pluses

$$NOP = \frac{T_{mach}}{T_{on}+T_{off}}$$

MRR for multi spark is calculated as follows

$$\mathbf{MRR - NOP \times MRR_{(1)}}$$

The structural analysis is carried out and deformed & un-deformed shaped is seen in the fig 3 and it is observed that the work piece is having very less deformation and can sustain the given heat flux applied on it.[11,12]

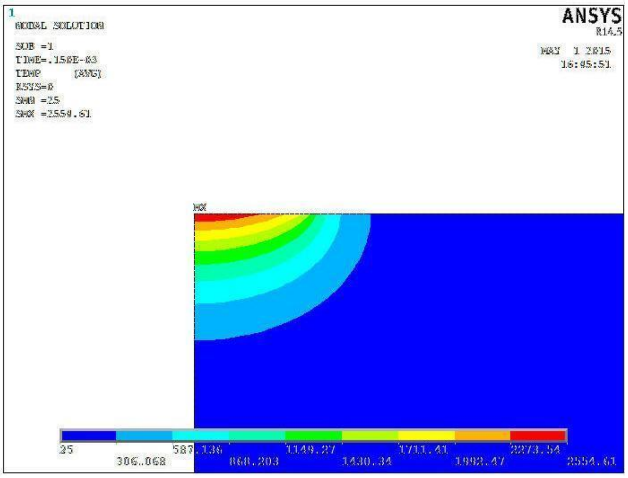


**Figure 2.** Nodal temperature distribution

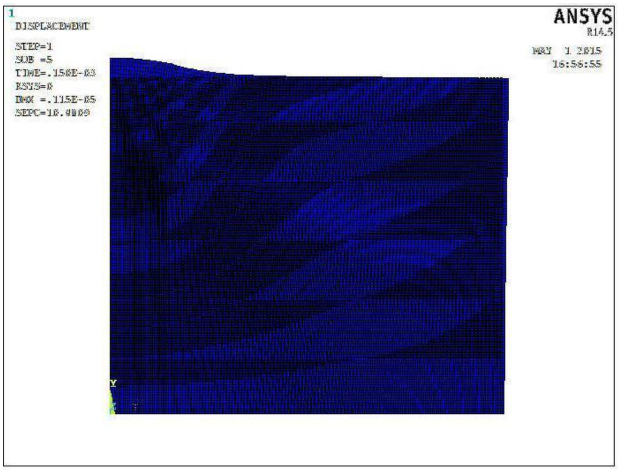


**Figure 3.** Deformed & Un-deformed shape

**Table I**. Analysis Result

| *CURRENT (A)* | *VOLTAGE(V)* | *MRR(mm³/min)* |
|---|---|---|
| 5 | 240 | 12.32 |
| 8 | 240 | 16.74 |
| 10 | 240 | 45.63 |
| 16 | 240 | 64.72 |
| 22 | 240 | 93.14 |
| 36 | 240 | 132.09 |

### C. Experimental Procedure

Experiments were performed with discharge current as variables. The discharge currents selected for this study were 5, 10, 15, 22, 25, 30 amperes to find Metal Removal Rate (MRR), Surface finish. The metal removal rate, were calculated by measuring weight difference of work piece before and after machining. At every current value the machining was carried out for time duration of 10 min. The metal removal rate were measured by using the following formula[13,14]

$$MRR = \frac{1000 \times (W_{iw} - W_{fw})}{\rho_w \times (Machining\ time\ \ in\,\mathrm{min})}\,\mathrm{mm^3/min}$$

Where $W_{iw}$= Weight of the work piece before machining and $W_{fw}$ = weight of the work piece after machining. $\rho_w$ = density (grams/cm$^3$)

**TABLE II** Experimental Values

| *CURRENT (A)* | *VOLTAGE(V)* | *MRR(mm³/min)* |
|---|---|---|
| 5 | 240 | 11.35 |
| 8 | 240 | 17.08 |
| 10 | 240 | 49.73 |
| 16 | 240 | 73.47 |
| 22 | 240 | 102.69 |
| 36 | 240 | 147.56 |

The surface roughness of the machined surfaces was measured with surface roughness measuring instrument SURFTRONIC 3+[15], presented in Fig 4. The $R_a$ values were measured to quantify surface finish.

As the discharge current increase the surface roughness valve also increase and it is plotted in the graph as shown below fig.4

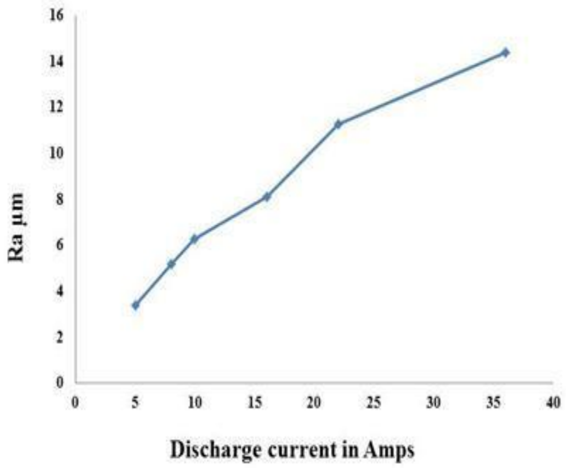


**Figure 4.** Variation of surface roughness with discharge current for Al-Ti Alloy

## III. RESULTS AND DISCUSSION

Results have been obtained for the single spark and considering Al-Ti Alloy as work piece material. Temperature distribution in the work piece has been carried out and it is clearly evident that the maximum temperature occurs at the top surface on the center line of the work piece, where the intensity of heat flux is maximum according to Gaussian distribution of heat flux. After the application of heat flux, it is evident from the FEA model that the temperature distribution during the spark, in the work piece is sufficient enough to melt the material due to its low melting temperature

**Model Validation**

Model validation has been done by comparing the predicted MRR with the experimental results Fig.5 shows the comparison between theoretical MRR and experimental values.

There were some deviations in the model when compared to the experimental data, this could possibly be due to some simplifying assumptions taken in the present numerical model like100 percentage flushing efficiency, no ignition delays, no deposition of recast layer, etc.[15,16] In practice, the melted material is not fully flushed from the crater, a considerable amount of melted material again solidifies in the crater and forms the recast layer. The ideal conditions for machining are not realized due to improper flushing of debris and arcing into the inter-electrode gap during the machining with high energy discharges thus, reducing the actual MRR. The MRR is mainly influenced by spark gap, lift, sensitivity and dielectric fluid. In present analysis dielectric fluid is not playing an important role. It is coming into picture only for convection, but in actual it is a very important factor to be considered while machining. The material removal is mainly caused by melting and vaporization of material. Molten metal is taken away by the dielectric fluid, but at the same time the molten metal are under very high pressure due to plasma channel. Adhesive property of molten metal also caused problem in material removal. However, it is very difficult to model and incorporate all these effects in the analytical model.

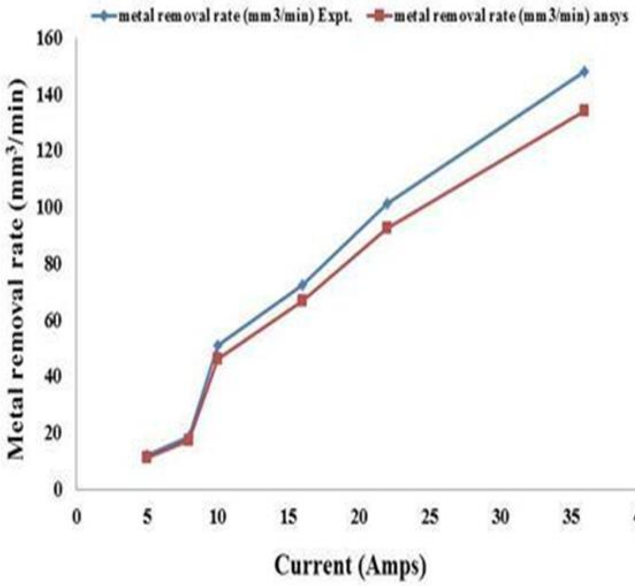


**Figure 5.** Variation of metal removal rate with discharge current for Al-Ti Alloy

## IV. CONCLUSION

a) In the present investigation, an axisymmetric thermal model is developed to predict the material removal rate in Al-Ti Alloy
b) In the present investigation, an axisymmetric thermal model is developed to predict the material removal rate in Al-Ti Alloy
c) The important features of this process such as individual material properties, shape and size of heat source (Gaussian heat distribution), percentage of heat input to the work piece, pulse on/off time are taken into account in the development of the model.

d) FEA based model has been developed to analyze the temperature distribution and its effect on material removal rate.
e) To validate the model, the predicted theoretical MRR is compared with the experimentally determined MRR values.
f) A very good agreement between experimental and theoretical results has been obtained.

## D. REFERENCES


[1]. C. Leyens, M. Peters (Eds.), Titanium and Titanium Alloys, WILEY-VCH Verlag, 2003

[2]. L. Gu, L. Li, W. Zhao and K. P. Rajurkar // International Journal of Machine Tools and Manufacture 53 (2012) 100.

[3]. Atul Kumar,DR.D.K.Singh, "Performance Analysis of Wire Electric Discharge Machining (W-EDM)", International Journal of Engineering Research & Technology (IJERT), Vol. 1 Issue 4,2-9,2012.

[4]. Yang, X., Liu, C.R., "Machining Titanium and Its Alloys", Machining Science and Technology 3(1), pp. 107-139, 1999.

[5]. Kuriakose, Sh., Shunmugam, M.S., "Characteristics of Wireelectro Discharge Machined Ti6Al4V Surface", Science Direct (Elsevier) 58, pp. 2231- 2237, 2004.

[6]. Gu, L., Li,l., Zhao, W., Rajurkar, K.P., "Electrical Discharge Machining of Ti6Al4Vwith a Bundled Electrode", International Journal of Machine Tools & Manufacture, 53 (1), pp. 100-106, 2012.

[7]. D.F.Hasson, C.H.Hamilton, Forward, Editors: D. F. Hasson and C. H. Hamilton, "Advanced Processing Methods for Titanium", the Metallurgical Society of AIME, 1982.

[8]. K.H. Ho, S.T. Newman, S. Rahimifard, R.D. Allen, "State of the art in wire electrical discharge machining (WEDM)", International Journal of Machine Tools & Manufacture, 44, pp. 1247–1259, 2004.

[9]. Rao RV, Pawar PJ., "Modeling and optimization of process parameters of wire EDM", Proc. IME B, Journal of Engineering Manufacturing, 223(11), pp. 1431–1440, 2009.

[10]. Electric discharge machining of Al–SiC metal matrix composites using rotary tube electrodeB. Mohana,, , A. Rajaduraib, K.G. Satyanarayana Available online 19 June 2004 Volumes 153–154, 10 November 2004, Pages 978–985 Proceedings of the International Conference in Advances in Materials and Processing Technologies.

[11]. Numerical analysis of the electro-discharge machining process for alumina-titanium carbide composite II. unsteady state approach Young-CheolAhn, Young-Seup Chung Korean Journal of Chemical Engineering July 2002, Volume 19, Issue 4, pp 694-702

[12]. C.A.C Antonio, J.P.Davim, Optimal cutting conditions in turning of particulate metal matrix composites based on experimental and a genetic search model, Composites: Part A 33 (2002) 213-219

[13]. Z.F. Zhang, L.C. Zhang, Y.W. Mai, wear of ceramic particle-reinforced metal matrix composites: Part I. Wear mechanism, journal of material science 30(1995) 1961-1966

[14]. J.P.Davim, A.M.Baptista, Relationship between cutting force and PCD cutting tool wear in machining silicon carbide reinforced aluminum, Journal of Material Processing Technology 103 (2000) 417-423

[15]. J.P.DavimDaimond tool performance in machining metal matrix composites, Journal of Material Processing Technology 128 (2002) 100-105

[16]. J.E.Allison, G.S. Cole, metal matrix composite in the automotive industry: opportunities and challenges, JOM (January 1993) 19-24

[17]. L.A. Cronjager, D. Meister, Machining of fibre and particle-reinforced aluminium, Ann. CIRP 41 (1) (1992) 63-66

[18]. S. Madhukar, A. Shravan, P. VidyanandSai and Dr. V.V. Satyanarayana, A Critical Review on Cryogenic Machining of Titanium Alloy (Ti-6Al-4V). International Journal ofMechanical Engineering and Technology, 7(5), 2016, pp. 38–45.http://www.iaeme.com/ijmet/issues.asp?JType =IJMET&VType=7&IT