Electrical Discharge Machining (EDM) On Titanium alloy workpiece using graphite

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Abstract

The production of titanium alloy in modern industry is increasing with the increasing use on a daily basis. Because of its multiple advanced features, Titanium and its alloys are now used in a variety of fields such as aerospace, satellites, sports cars, etc. Specifications or characteristic features of Titanium and alloys are being discussed in this article. Advancements in same field by different researchers is briefly explained.As a result, it is replacing other metals such as aluminium in a variety of applications. The alloys of titanium termed as super alloys due to their high corrosion resistance and high strength – to – weight ratio. In this article non- traditional machining processes - EDM process are being used for machine these type of hard materials. EDM has a higher surface finish rate and can machine complicated geometry and profiles, it is preferred. Hence no mechanical vibrations produced in machining procedure.

Keywords: EDM, MRR, SR, TWR, ANOVA

1. INTRODUCTION

Non-traditional machining process for machining purpose is employed for hard materials like Electrical discharge machining (EDM) is a in which the tool and work piece have no contact. [1] EDM is a stochastic process that combines various disciplines. It has been widely used in the machining of various conductive materials. During the electrical discharge machining process, the surface of the electrode, tool, and work piece are all modified. [2] The machining parameter influences machining characteristics such as surface integrity and machining accuracy. Product quality is also affected by process parameters. The best manufacturing conditions can be obtained by optimising process parameters. Electrical discharge machining has grown in popularity as a highly effective and profitable machining technique. [3] Because manufacturing costs are also affected by product quality. It is necessary for the machine to operate at the proper parameters in order to produce a higher-quality product. Many researchers are working on increasing the material removal rate and attempting to reduce tool wear rate through experimental investigation. Because EDM is free of mechanical stress and chatter, it can achieve close tolerance on dimension. Many techniques, such as magnetic field assisted and vibration assisted, have been used to promote the manufacturing process since the development of EDM. Nano EDM and wire cut EDM are used in modern industry to improve production quality. EDM provides reliability in production, so several studies are currently being conducted to determine how to achieve stable discharge. Because the parameters of the machine are selected based on the operator's experience, the operator's experience is a critical factor in increasing the production rate. The majority of data in modern industry is supplied by the manufacturer. Ceramics, on the other hand, are used for advanced materials such as super alloys. Because these advance material data are not available, the operator is in a bind. As a result, optimising process parameters is critical for this type of material. It is a critical procedure. Sparks are produced between the cathode and the anode. Material is removed from the work piece through melting and evaporation. Both the anode and the cathode should be made of conductive material. Through a series of electric discharges, electric energy is converted into thermal energy, and a plasma channel is formed between the anode and cathode. EDM has some limitations, such as a longer lead time and a high specific consumption. Many researchers are working to overcome this type of limitation. To increase productivity, various models, such as RSM and the Grey relational technique, have been developed. Atoms are broken down in the electric medium due to the potential difference between the anode and cathode. The temperature in the spark zone is extremely high, and the radius of the spark is extremely small. Because of the higher temperature value of the spark, it is capable of melting and vaporising the material from both the anode and cathode. The work piece is anode, and the tool is cathode. EDM can be used to machine difficult and complex shapes. [4] It is used in the machining process of tool and dies sinking. [5] The “Ra” abbreviation is used for the average surface roughness.

2. **Literature review**

Research developments in the EDM process by other Researchers in chronological order is being discussed in table 1. In year 2018 multiple researchers provided their concluded theory about EDM processing on different hard materials.

**Table 1: Developments in the EDM on different work piece.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| AUTHOR | Research work | WORK PIECE | ELECTRODE MATERIAL | MACHINING PARAMETER | PERFORMANCE PARAMETER |
| Pal et al.[15]  | Parametric optimization of EDM using Annova and Taguchi | Stainless steel | Tubular copper | Pulse on time, Pulse off time, Discharge current, Fluid pressure | MRR, TWR |
| Mohanty et al. | Optimization in EDM of D2 steel with multiple surface roughness characteristics using Hyprid Taguchi method | D2 steel | Brass,copper,DMLS electrode | Pulse on time, Pulse off time, Discharge current, fluid pressure | MRR,EWR,Surface Roughness |
| Kumar et al. | Analysis of MRR and surface roughness  | Titanium alloy | Copper electrode | Current, voltage, pulse on time | MRR,TWR,Surface Roughness |
| Ubaid et al. | Optimization of EDM process parameters with fuzzy logic  | Stainless steel | copper | current, pulse on time, pulse off time | MRR,TWR,Surface Roughness |
| Ragavindran et al. | Sensitivity analysis and optimization of EDM process parameter | steel | copper | Pulse on time, current, concentration of powder | MRR, EWR |
| Sahu et al. | Optimization of EDM machining parameters | Inconel - 825 | Copper tool | Current, Pulse on time, Flushing pressure | MRR, TWR, surface roughness |
| Kakkar et al. | Optimization of surface roughness , material removal rate, and tool wear rate in EDM using Taguchi method | Al-Sic (metal matrix composite) | copper | Voltage, Pulse on time, Discharge current | MRR,TWR ,Surface Roughness |
| Rahul et al. | Effect of tool electrode on EDM performance of Ti-6Al-4V | Ti-6Al-4V | Tungsten, normal copper, cryogenically treated copper  | Peak discharge current | Material removal efficiency, Surface roughness, surface crack density, white layer thickness |

**3. Experimental. Method**

Electronica ZNC EDM machine was used for machining the samples. EDM is non-conventional machining process .Many input parameters like discharge voltage, pulse on time, Pulse off time, Peak current, dielectric pressure can be varied in EDM process. Each effect has its own effect on output parameter .output parameter such as material removal rate, Tool wear rate overcut size etc. and geometrical accuracy. It is affected by input parameter.

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**Fig 1 - Electric discharge machining set up**

**Table 3.1 Technical Specifications of EDM**

|  |  |  |
| --- | --- | --- |
| **Sr.No.** | **Specification** | **Value** |
| **1** | Model | ZNC |
| **2** | Dielectric Fluid | EDM Oil |
| **3** | Input Power Supply | Three phase AC 415V,4 wire system,50Hz |
| **4** | Electrode used | graphite |
| **5** | HXWXD machine size | 1750X1060X525 mm |
| **6** | Maximum Load Lift | 750 Kg |
| **7** | Pulse on time | 0.5 to 4000 |
| **8** | Pulse frequency | .1 to 500 |
| **9** | Main Table Transverse | 1100X650 mm |

3.1**Selection of work piece**

The work piece material used in this experiment titanium alloy (Ti-6Al-4V).The selected material is 115 mm x55 mm x 5mm .It has chemical follows as.



**Fig 2- Titanium alloy work piece**

**Table 3.2 – Chemical composition of (Ti-6Al-4V)**

|  |  |
| --- | --- |
| C | 89.46 |
| Al | 6.08 |
| V | 4.02 |
| Fe | 0.22 |
| O | 0.18 |
| C | .02 |
| N | .01 |
| H | .053 |

3.2 **Selection of Electrode**

A cylindrical shape pure graphite of diameter 10 mm is used for machining design.



**Fig 3 – Figure of Graphite tool**

**Table 3.3 – Graphite tool properties**

|  |  |
| --- | --- |
| Properties | Value |
| Density | 1.75 g/cm3 |
| Melting Point | 4550 C |
| Electrical Resistivity | .12 micro ohm/cm |
| Electrical Conductivity | .11% with silver |
| Thermal conductivity | 160 W/Mk |
| Specific Heat | .17-0.2 cal /g0C |
| Coefficient of thermal expansion | 7.8\*10-6C-1 |

**3.3 Objective of the present work**

. This study entails to analyze the impact of rotary tool electrode EDM (EDD) on high temperature resistive materials i.e. Titanium metal for two output parameters MRR and *Ra*

**MethodologY used in Present Work**

**4.1Experimental set up**

The present study has been conducted on the developed set-up (already) of one of the past researchers. The brief description of the set-up is described below so as to appreciate the obtained study results. The used set of EDD has been designed and taking entire current, duty factor and tool rpm consideration of technical requirements and special consideration to weight and vibration. This setup has been installed on the ram of ZNC EDM machine after replacing actual tool holder of this die-sinking EDM machine. In this setup, one Rotomag (India) make electrical permanent magnet direct current (PMDC) motor of 0.193 kW and 1200 rpm is mounted vertically on one of the 14 mm thick aluminum alloy plate, which is fixed (butted) vertically on another horizontal plate of same material. Mounting bolts of the DC motor are provided with insulated glass sleeves so that DC current does not passes from Al-alloy plate to electric DC motor.

 A housing assembly provisioned in the setup with rotating spindle made of mild steel is mounted on horizontal plate. The spindle is supported on four angular contact ball bearings in housing, so that axial thrust load is taken care of and there is minimum axial as well as radial play. The selection of these two angular contact ball bearings is done based on the expected load, motor power, motor rpm and endurance run during experimental work of EDM machining. A driven pulley is mounted at one end (top) of rotating spindle. The lower side of spindle has a cylindrical bore of 7.0 mm diameter up to the length of 6 mm in which tool electrode is inserted and tightened with help of two tightening screws. A variable speed controller is connected in the input circuit of the motor for controlling the rpm of electrical motor up to 1200 rpm. A diode of 2 A is connected at input terminal of electrical motor as a safety measure for the motor of any inadvertent phase connection.

The round rod was machined and the workpieces were sliced of 4 mm thickness disc by wire cut EDM machine. A through hole was drilled using graphite electrode using EDM with rotating tool electrode. After measurement of MRR, the machined workpieces were partitioned into two half to facilitate the accurate measurement of *Ra.*



1. (b)

Fig. 4.1 Photograph of (a) workpiece (b) Workpiece of hole made

**5.1 Average Surface Roughness**

**5.1.1 Effect of current**

Fig. 5.1

 *Ra* increases from 2.6to 3.90µm i.e. increase by 39.60% with increase of current from 12 to 20 A and similar trend is seen for all other duty factors. This is because, as the current increases, the intensity of spark increases. This leads to more amount of heat along with power discharge increases, resulting large and appreciable depth of crater is obtained at increased duty factor, which has been, observed in the form of larger*Ra* value on the machined work piece

 Fig 5.1 for *R*a vs current of Titanium alloy

**5.1.2 Effect of Duty factor**

Fig. 5.2 shows the variation of *Ra* with varying duty factor at different tool rpm on 12Acurrent. In fig. 5.2a at 600rpm the value of *Ra* increases from 4.1 to4.59µm with increase of duty factor 62to69 %i.e increase by 15%.The further trend is found to be decreasing *Ra* value with increasing tool rpm. This is due to the improved flushing of eroded debris from spark gap, resulting improved *Ra* along with increasing tool rpm. The improvement of *Ra* at higher tool rpm is also due to the effect of improved melting of material from the work piece at increasing duty factor.

Fig. 5.2 Effect of duty factor on *Ra* for different tool rpm of Titanium alloy

**5.1.3 Effect of Tool Rotation**

Fig. 5.3 show the variation of *Ra* with varying tool rpm on different current at 62% duty factor .In fig5.3 it is observed that *Ra* almost improves or seems to be constant with increasing of tool rpm for all current. It is noted that *Ra*has varies between 3.0to 3.90 µm for all current values. This is because of the effective melting of materials and improved flushing as result of the rotation of the tool electrode.

Fig. 5.3 Effect of tool rpm on *Ra* for different current on Titanium alloy

 **Material Removal Rate (MRR)**

**5.2.1 Effect of current**

InFig. 5.4bit is observed that 62% duty factor MRR increases by 12.35% (from 53.2 to 60 mg) with increasing current from 12 to 20A and similar trend is found for all other duty factor. This is because more heat generated with increasing gap current and material get melted thereof.

Fig. 5.4 Effect of gap current on MRR for different duty factor on Titanium alloy

**5.2.2 Effect of Duty factor**

InFig. 5.5 it has observed that at 600rpm MRR increases by 21.82 %(from44to54mg) with increasing duty factor from 63to 70%and similar trend is seen for all other tool rpm .This is credited to improved flushing of eroded debris from spark gap along with the increased heat energy due to the increased duty factor.

Fig. 5.5Effect of duty factor on MRR for different tool rpm on Titanium alloy

**5.2.3 Effect of Tool Rotation**

In Fig. 5.6 it is observed that MRR increases with the increase of tool rpm for all the current. It is noticed that at maximum value of current (at20A), MRR has been found maximum which has varied from64to74mg.This is because of the effective melting of materials with increasing of current along with increasing of tool rpm. The increasing of tool rpm has certainly enhanced the flushing of eroded debris from the machined surface, as result MRR increases.

Fig. 5.6 Effect of tool rpm on *MRR* for different current on Titanium alloy

**CONCLUSION**

The conclusions drawn of research comparative study related to the parametric, EDD of titanium alloy

Though there has been a substantive improvement in conventional as well as nonconventional machining techniques, still the challenges for efficient, cheaper and reliable process for machining of tailored made materials (advanced materials) does exist, which hampers the growth of aerospace industry.

* Today’s sinking EDM is primarily used in industries to make the holes and channels in inaccessible area of the complex designed components where twist drill surrenders.
* The developed EDD process has been able to machine such difficult to cut materials with enhanced performances as this experimental study of Titanium alloy confirms.
* Surface roughness increases with increase of current and duty factor, but at increased tool RPM it improves due to better flushing of eroded debris from *IEG*.

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