Influence of Process Parameters on Surface Roughness of Titanium Alloy Ti-6Al-4V through Electro Discharge Machining

K.C. Sabitha

Assistant Professor, Dept.of Mechanical Engineering, Mahatma Gandhi Institute of Technology, Gandipet, Hyderabad-500075.

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Abstract - *Electro-discharge machining (EDM) is widely used non-traditional machining process in the present manufacturing scenario. The electro-discharge machining has been widely used in the production of dies and molds. Basically, EDM is used to machine those materials which are difficult to machine by the conventional machining process. There is no direct contact between the tool material and work-piece. The material is removed by the thermal erosion in the EDM process. The material removal rates are less in the EDM than the other conventional machining processes. The major advantage of using EDM rather than conventional machining processes is very high surface finish rates. The advantage of using EDM there are no mechanical vibrations and mechanical stresses occurs during machining because of no direct contact between the work-piece and tool material and also that it can machine any profile or geometry. It can easily machine the complicated geometry which can be difficult to machine by some other machining processes. But the limitation is only the tool material and work-piece must be electrically conductive. Finishing parts of aerospace and automobile industries are machined by the EDM process. Machining of Titanium alloy Ti-6Al-4V is carried out using EDM process. This material provides excellent corrosion resistance, a high strength to weight ratio and good high temperature properties. Titanium and its alloys are classified as difficult to machine materials by conventional machining methods. The main difficulties in machining them are high cutting temperature and rapid tool wear. Therefore, for machining this material, unconventional machining processes are recommended. EDM is the widely capable to machine the hard materials such as alloys, composite and even the ceramics also. EDM has wide range of application in automobile, aerospace, defense and precision engineering industries. This paper presents evaluation and influence of process parameters on surface roughness of titanium alloy Ti-6Al-4V through brass electrode using electro discharge machining process.*

Key Words: **Electro-discharge machining, Ti -6Al-4V, Process parameters, Dielectric, Surface roughness**.

1. INTRODUCTION

In the current manufacturing scenario, the industrial product not only requires the high precision and quality but should be produced in the minimum time in order to sustain their position in the global market competition. Thus, it is required to regulate the input process parameters for achieving the desired output or the performance. The electro discharge machining (EDM) technique is developed in the 1940 by two Russian Scientist B.R Lazarenko and N.I Lazarenko. Later in 1967 the scientists of Soviet Union developed first EDM in which they used wire as the electrode. EDM utilizes the electrical energy to generate the electrical spark and the material removal is done by the thermal energy that is generated by the electrical spark [1-3]. A small gap known as spark gap which is 0.005mm-0.05mm.is maintained between the tool material and work-piece.

There are the continuous electrical charges occurring between the tool and work-piece in the presence of the dielectric fluid. The dielectric fluid may be the EDM oil and kerosene oil. The main purpose of dielectric fluid is to provide the dielectric medium and flushing out the machining debris from the work table. The major disadvantage of the EDM is the overcutting and the formation of the recast layer. When the DC supply is given then the electric spark is generated and the ions starts flowing from the work-piece and electrons from the tool material [4-6]. The electric field is generated between the work-piece and the tool and it is maximum where the gap between the work-piece and tool is minimum. With the increasing demand for new, hard, high strength, hardness, toughness, and temperature resistant material in engineering, the development and application of EDM has become increasingly important [7]. EDM has been used effectively in machining hard, high strength, and temperature resistance materials.

Material is removed by means of rapid and repetitive spark discharges across the gap between electrode and work piece. In addition, mechanical and physical properties of titanium such as excellent corrosion resistance, a high strength to weight & good high temperature properties has made it an important material for engineering components particularly in aerospace and automotive industries, and also used as medical implant material in wide range of application [8-10]. Since the EDM process does not involve mechanical energy, the removal rate is not affected by either hardness, strength or toughness of the work piece material. Therefore, a comprehensive study of the effects of EDM parameters (peak current, machining voltage, pulse duration and gap) on the machining characteristics such as electrode wear rate, material removal rate, surface roughness and etc., is of great significance and could be of necessity. The Effect of pulse-on-time, on the EDM performance is observed by varying peak current while the other parameters like pulse-off-time, voltage and gap kept constant. It is observed that the MRR is increasing with the pulse-on-time at all the values of current and surface quality of material starts decreasing when there is an increase in the value of pulse-on-time [11]. Optimum values of surface roughness can be found at the lower value of pulse-on-time and current. The Effect of peak current to investigate the effect of peak current in EDM on MRR and surface roughness pulse on time varied and other parameters like pulse off time, voltage and wire feed rate kept constant. The material removal rate is low at lower values of current and it is nearly constant as the values of current are low [12-15]. The material removal rate of material starts increasing with the increasing value of current. Effect of servo voltage, the effect of servo voltage on the performance of EDM is observed by varying the pulse duration and keeping all other parameters constant MRR starts increasing with increase in the servo voltage initially. But then starts decreasing with increase in the servo-voltage. On other hand surface quality of material also starts decreasing with increase in the voltage.

2. DETERMINATION OF SURFACE ROUGHNESS

The machining is carried out on ElectronicaC-425 EDM set up. Titanium Alloy (Ti 6Al 4V) is used as the work material with a cylindrical brass electrode of 10 mm diameter & 80mm length & SPO oil as dielectric oil. Figure1 depicts schematically the experimental setup.

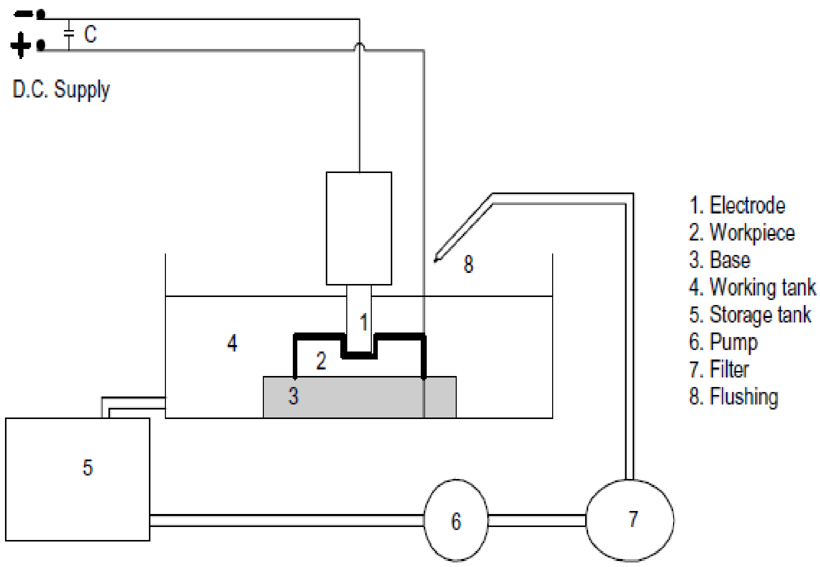

Fig -1: Electro Discharging Machining Process

Table-1 & 2 shows the material related properties:

Table -1: Physical properties for Ti-6Al-4V

Density g/cm^3 (lb/ cu in)	4.42 (0.159)
Melting range °C ±15°C (°F)	1649 (3000)
Specific Heat J/Kg.°C (BTU/lb.°F)	560 (0.134)
Volume Electrical Resistivity ohm.cm (ohm,in)	170 (67)
Thermal Conductivity W/m.K (BTU/ft.h.°F)	7.2 (67)

Table -2: Typical mechanical properties of Ti-6Al-4V

Hardness, Rockwell C	36
Tensile Strength, Ultimate	950 Mpa
Tensile Strength, Yield	880 Mpa
Modulus of Elasticity	113.8 GPa
Poisson 's Ratio	0.342

The experiment is conducted using Taguchi method of experimental design & an appropriate orthogonal array L9 is selected after considering the design variables (Peak Current, Pulse on time, Gap).The effect of variation in input is studied on three response parameters & experimental data analyzed as per Taguchi method to find out optimum machining conditions to optimize process parameters. To attain a more accurate result, each combination of experiment was replicated three times. Changes in electrode weight, material weight and elapsed time will be recorded after each machining test. The MRR and the EWR were evaluated for each cutting condition by measuring the average amount of material removed and the required cutting time. The material removal rate & electrode wear rate will be estimated by their weight loss. The roughness indices are measured by Taylor Hobson surface roughness measuring instrument. The Ra values will be measured three times on each specimen and then, the surface roughness values will be averaged for accuracy. The effect of electrode material brass on surface roughness (SR) is studied. These electrode were machined to a cylindrical shape of 10 mm diameter & 80 mm length. The surface roughness was evaluated for optimum machining conditions for this electrode.

Machining experiments for determining the optimal machining parameters is carried out by setting voltage in the range of 120-200 V, the discharge current in the range of 6.0–18.0 A, the pulse duration in the range of 30-90µs, and the Gap (Voltage between electrode & work piece) in the range of 1-20. Essential parameters of the electrical discharge machining experiment are given in Table 3.

Table -3: Electrical Discharge Machining Condition

Work Condition Description	
Electrode	Carbon
Work piece	Titanium alloy(Ti 6Al4V), rectangle shape(100x90x10mm)
Input current	2-20A
Pulse on time	1-100 µs
Gap	1-20 mm
Dielectric Fluid	SPO Oil
Electrode materials	Brass

The experimental layout for the machining parameters using the L9 orthogonal array is used in this study. This array consists of three control parameters and three levels. In the Taguchi method, most all of the observed values are calculated based on 'the higher the better' and 'the smaller the better'. Thus in this study, the observed values of MRR, EWR and SR will be set to maximum, minimum and minimum respectively. Each experimental trial will be performed with three simple replications at each set value. Next, the optimization of the observed values is determined by comparing standard analysis which is based on the Taguchi method.

3. RESULTS AND DISCUSSION

Taguchi method using design of experiments approach can be used to optimize a process Here D.O.E approach for modeling of Surface roughness (SR) in EDM process is used and the various input parameters will be taken under experimental investigation and then model was prepared and finally experiments were performed. The optimization will help in improving the life of work piece, material as well as the effective and efficient working of the EDM machining process. The process parameters assignment as shown in Table 4.

Table -4: Parameter Assignment

Parameters	Level1	Level2	Level3
Peak Current(Amps)	6	12	18
Pulse on time(μs)	30	60	90
Gap(mm)	10	12	18

Evaluated and study of surface roughness for Titanium alloy Ti-6Al-4V through electro discharge machining with consideration of various process parameters such as current, pulse on time and Gap. The effect of process parameters current, pulse on time and Gap on surface roughness of Titanium alloy Ti-6Al-4V are presented in fig.2, fig.3, and fig.4.

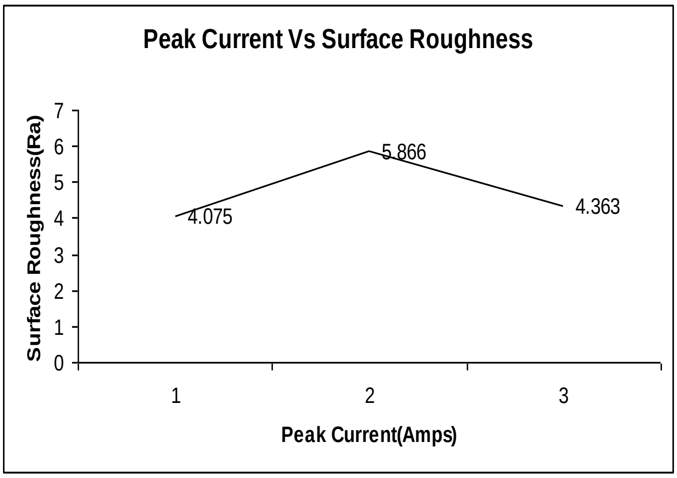

Fig-2: Influence of Current on surface roughness

From fig.2, The surface roughness increased with the increase in the peak current till a particular level of current and later the surface roughness decreased even with an increase in peak current. At level 1: current 6Amps, Surface roughness Ra is 4.075 μm, at level 2: current 12Amps, Surface roughness Ra is 5.866 μm and at level 3: current 18 Amps, Surface roughness Ra is 4.363μm. The highest surface roughness obtained at current 12Amps and lowest surface roughness obtained at current 6Amps.

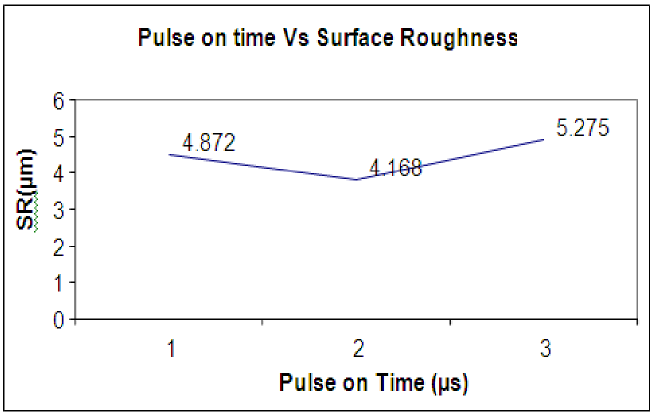

Fig-3: Effect of Pulse on time on surface roughness (SR)

From fig.3, The surface roughness is decreasing with increase in pulse on time till a level and after which the surface roughness is increased with increasing in pulse on time. At level 1: Pulse on time 30μs, Surface roughness Ra is 4.872μm, at level 2: Pulse on time 60μs, Surface roughness Ra is 4.168 μm and at level 3: Pulse on time 90μs, Surface roughness Ra is 5.275μm. The highest surface roughness obtained in titanium alloy Ti-6Al-4V at pulse on time 90μs and lowest surface roughness obtained at pulse on time 60μs.

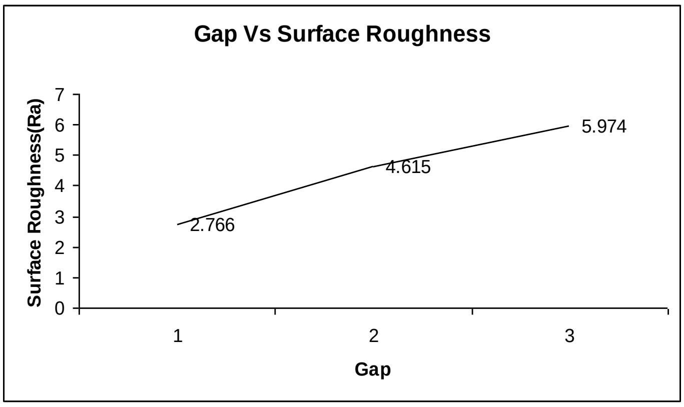

Fig-4: Effect of Gap on surface roughness

From fig.4, The surface roughness is increasing with increase in the level of gap. At level 1: Gap 10mm, Surface roughness Ra is 2.766µm, at level 2: Gap 12mm, Surface roughness Ra is 4.615 µm and at level 3: Gap 18mm, Surface roughness Ra is 5.974µm. The lowest surface roughness obtained in titanium alloy Ti-6Al-4V at gap of 10mm and highest surface roughness obtained at gap of 18mm.

4. CONCLUSIONS

Conclusions are drawn from present research work on influence of process parameters on surface roughness of titanium alloy Ti-6Al-4V through electro discharge machining using brass electrode. The surface roughness is measured by Taylor Hobson instrument. Taguchi method has been used to determine the main effects, significant factors and better conditions to the performance of Electro discharge machining.

- The lower surface roughness (SR) is achieved at Level 1; current of 6 Amps with Surface roughness Ra 4.075 µm.
- The lower surface roughness (SR) is achieved at Level 2; pulse on time of 60 µs with Surface roughness Ra 4.168 µm.
- The lower surface roughness (SR) is achieved at Level 1; gap of 10mm with Surface roughness Ra 2.766 µm.
- Finally it is observed that minimum surface roughness is achieved at current of 6Amps, pulse on time 60µs and Gap 10mm.
- These are the better values were obtained for surface roughness for titanium alloy Ti-6Al-4V through electro discharge machining process.
- The brass electrode produces high surface finish.

EDM process offers to enables high accuracy on tools and dies, because they can be machined in hard conditions. It is even highly dedicated to sections and weak materials without any fear of distortion because there is no direct contact between the tool and the work piece. Irrespective of its hardness or strength, any material, which is electrical conductor, can be machined. Any shape that can be imparted to the tool can be reproduced on the work. It is a quicker process. Even harder materials can be machined at a much faster rate than conventional machining. EDM is one of the widely used unconventional machining method that is capable of producing the complex shapes. The only limitation in the EDM is the work piece should be conductive in nature.

The surface produced by the EDM process consists of a multitude of small craters randomly distributed all over the machined face. The quality of surface finish depends upon energy per spark. If energy content is higher deeper crater will result leading to poor surface. The surface roughness has been found to be inversely proportional to frequency of discharge. On other hand surface quality of material also starts decreasing with increase in the voltage. Taguchi method is that it emphasizes a mean performance characteristic value close to the target value rather than a value within certain specification limits, thus improving the product quality. Taguchi method allows for the analysis of many different parameters without a prohibitively high amount of experimentation.

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