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Investigations on Surface Characterisation of Wire Electric Discharge Machined Surface of Titanium Alloy

Siva Prasad Arikatla[1], K. Tamil Mannan[2] and Arkanti Krishnaiah[3]

[1]*D.A. Government Polytechnic, Ongole, Andhra Pradesh, INDIA.*
[2]*School of Engineering & Technology, IGNOU, New Delhi, INDIA.*
[3]*UCE, Osmania University, Hyderabad, Andhra Pradesh, INDIA.*

Abstract

Titanium and its alloys are used in many different industries such as biomedical and medical applications, automobile, aerospace, chemical field, electronic, gas and food industry because of its extreme properties like high tensile strength, fatigue resistance, highest strength-to-weight ratio, corrosion resistance, toughness at elevated temperatures and able to withstand high temperatures. Wire electric discharge machining has become one of the most popular processes for producing precise geometries in hard materials like titanium alloy. Improper Wire electric discharge machining process parameters setting can affect the surface roughness, overcut, micro structural changes and totally affect the process performance and efficiency. This paper presents an experimental investigation of Wire Electric Discharge Machining of Titanium alloy. The objective is to investigate the effect of wire electric discharge machining process parameters including pulse on time, pulse peak current, spark gap set or reference voltage, wire feed rate, wire tension, water pressure and servo feed rate on surface roughness and surface topography. Experimental results reveals that, as the pulse on time or pulse duration, pulse peak current and servo feed rate increases the surface roughness was also increases. As the spark gap set voltage, water pressure, wire feed rate and wire tension increases the surface roughness decreases. However, for extended spark gap set voltage, water pressure, wire feed rate and wire tension, the surface roughness increases. Surface topography was also observed with optical micro scope (Model XJL 17) with magnification of X100 and Sensitivity of 0.01 mm. It is observed that surface roughness, craters and the density of global appendages and pockmarks were reflects the degree of surface topography.

Keywords: WEDM, titanium alloy, Surface roughness, surface topography.

1. Introduction

Wire Electric Discharge machining (WEDM) becomes an important non conventional/non traditional machining process due to its competency in machining of work pieces with complex geometry and hard stiffness. The development of new, advanced engineering materials and the need for precise and flexible prototypes and low-volume component production have made WEDM an important manufacturing process to meet such a demand. Unlike traditional cutting and grinding processes, which rely on the force generated by a harder tool or abrasive material to remove the softer work material, the WEDM process utilizes electrical sparks or thermal energy to erode the unwanted material and generate the desired shape. In WEDM process the material is removed by a series of discrete electrical discharges between the wire electrode and the work piece. The discharges, which are highly focused by the dielectric medium, cause rise in the local temperatures of the work piece near the point of introduction. D. Rakwal et al. stated that the temperatures are high enough to melt and vaporize the material in the immediate vicinity of the electrical discharges. Since, there is no mechanical contact between the work piece and the electrode, material of any hardness can be machined as long as it is electrically conductive. Garg RK et al and Sarkar S stated that due to this reason, it has dramatically increased in high application of materials with high stiffness in the aerospace, nuclear and automotive industries. WEDM was effective solutions for machining hard materials such as titanium, molybdenum, zirconium and tungsten carbide with complex shapes and profiles that are difficult to machine using conventional methods. The hardness and strength of the difficult to machine work material are no longer the dominating factors that affected the tool wear and hinder the machining process. This makes the WEDM process particularly suitable for machining hard, difficult to machine material. The WEDM process has the ability to machine precise, complex and irregular shapes with a CNC control system. In addition, the cutting force in WEDM process is small, which makes it ideal for fabricating parts with miniature features.

Titanium Ti-6Al-4V has become very popular materials and widely used as implants for dental, restorations and orthodontic wires, as well as orthopedic due to their low density, high corrosion resistance and excellent mechanical properties. P. Kovacs et al and B.Pan et al stated that however, these alloys were very difficult to fabricate as they are not ductile and have low fracture toughness at room temperature. Furthermore, due to its excellent strength property, it is found that it is extremely difficult to machine by conventional method. D.F.Hasson et al have been investigated the different aspects of machining but no comprehensive research work has been reported so far in the field of wire electrical discharge machining of this alloy. With improper of selecting parameters there are possibility of wire breakage imposes certain limits on the cutting speed, which in turn reduces productivity. Gauri SK et al and Rao RV et al. studied the modeling and optimization of WEDM process parameters. The selection of optimum cutting parameters is solution in obtaining a higher cutting speed or good surface finish. Machine feed rate, discharge current, wire speed, wire tension and average working Voltage are the machining parameters which affect the WEDM process performance measures. This study aimed in achieving the appropriate conditions in machining Titanium Ti-6Al-4V resulted in terms of surface roughness and surface topography.

2. Experimental Work

The experiments were conducted on ULTRACUT S1 Four Axis Wire Cut EDM from Electronica India Pvt. Ltd. The titanium alloy of Ti 6Al 4V was used as work piece material for the present Investigations. The chemical composition of T 6Al 4V titanium alloy by % weight is 0-0.08%C, 0-0.25%Fe, 5.5-6.76%Al, 0-0.2% O_2, 0-0.05%N_2, 3.5-4.5%V, 0-0.15%H_2 and rest of Titanium. A diffused brass wire of 0.3 mm diameter was used as the wire electrode and deionized water was used as dielectric. The process parameters such as pulse on time, pulse peak current, servo gap voltage, water pressure, wire feed rate, wire tension and server feed rate has taken at three different levels as shown in Table 2. The selections of these factors were based on the suggestions from the handbook recommended by the machine manufacturer, preliminary research results and journals. The surface roughness was measured with surf tester with sensitivity of 0.001 µm. The surface topography of WEDM surface of titanium alloy was observed with optical microscope with magnification of 100X. The influence of WEDM process parameters such as pulse on time, pulse peak current, servo gap voltage or reference voltage, wire feed rate, wire tension, water pressure and server feed rate on surface roughness and surface topography have been studies with reference to the experimental results.

Table 1: Test Conditions.

Process Parameter	L1	L2	L3
Pulse on Time (µs)	100	110	120
Pulse Peak Current	10	11	12
Servo Gap Voltage (V)	40	50	60
Water Pressure (PSI)	5	10	15
Wire Feed Rate (mm/min)	5	10	15
Wire Tension (kgf)	8	10	12
Server Feed Rate	50	1050	2050

3. Results and Discussions

3.1 Surface Roughness

The surface roughness was measured with surf tester with sensitivity of 0.001 µm along the direction parallel and perpendicular to wire. Experimental results reveals that, as the pulse on time, pulse peak current and servo feed rate increases the surface roughness was also increases. As the spark gap set voltage, water pressure, wire feed rate and wire tension increases the surface roughness decreases, as shown in fig 1. However, for extended spark gap set voltage, water pressure, wire feed rate and wire tension, the surface roughness increases. Spark gap set voltage, water pressure, wire feed rate and wire tension are significant parameters in obtaining the better surface finish. P.S.Rao et al. also proved the same. Suleiman Abdulkareem et al. has proved that wet WEDM can be used to improve surface roughness of Titanium work piece.

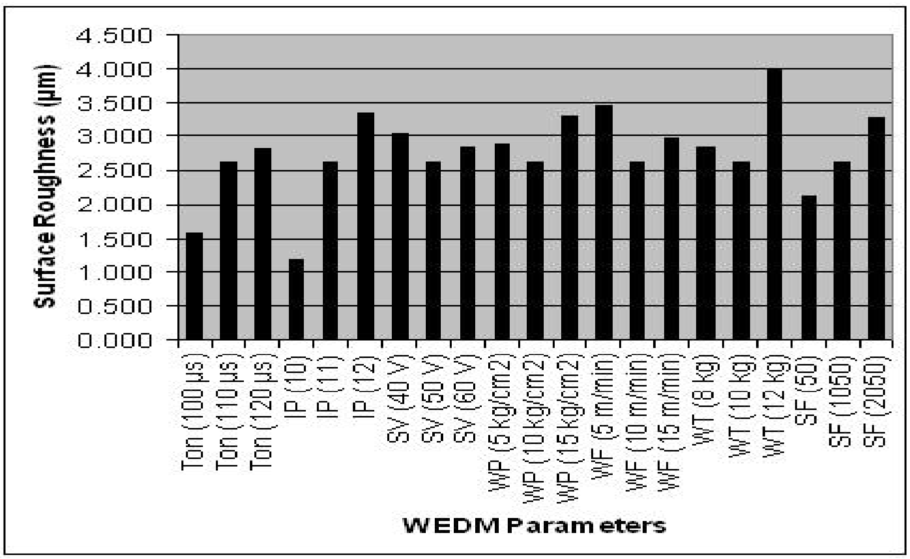

Fig. 1: WEDM parameters vs. Surface Roughness.

3.2 Surface Topography

Surface topography was observed with optical micro scope (Model XJL 17) with magnification of X100 and Sensitivity of 0.01 mm. Figure 2 (a) to 2 (n) shows the surface topography of each experiment at different test conditions. It is observed that surface roughness, craters and the density of global appendages and pockmarks were reflects the degree of surface topography. Experimental results reveals that, at higher pulse on time, pulse peak current and servo feed rate, the craters and the density of global appendages and pockmarks were high, as shown in fig. 2(b), 2(d) & 2(n). Further, as the spark gap set voltage, water pressure, wire feed rate and wire tension increases the craters and the density of global appendages and pockmarks were low, as shown in fig. 2 (f), 2(h), 2(j) & 2(l). However, for extended spark gap set voltage, water pressure, wire feed rate and wire tension, the craters and the density of global appendages and pockmarks were high. Lei Geng et al., stated that the fractal dimension of the multi-process is greater than the one of the single process, and the surface profile should be more complex and finer.

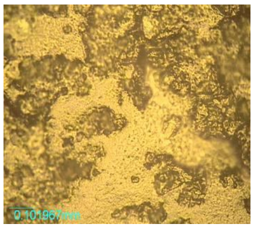

Fig. 2(a) Ton=100 µs

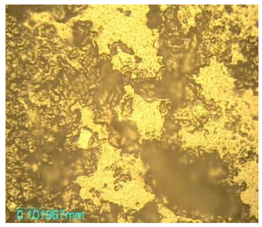

Fig. 2(b) Ton=120 µs

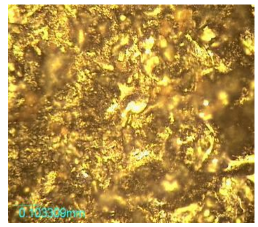

Fig. 2(c) IP=10

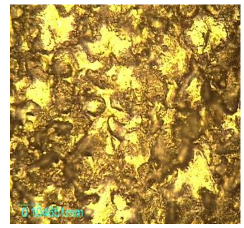

Fig. 2(d) IP=12

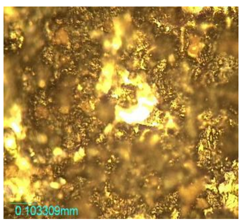

Fig. 2(e) V=40 v

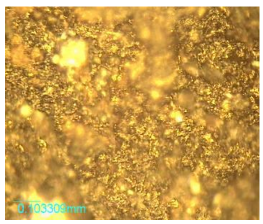

Fig. 2(f) V=60 v

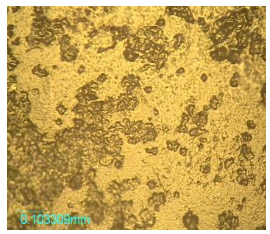

Fig. 2(g) WP=5 PSI

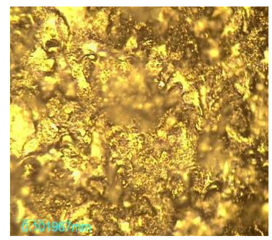

Fig. 2(h) WP=15 PSI

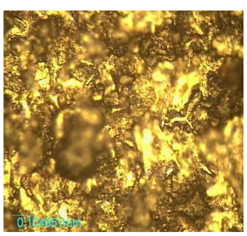

Fig. 2(i) WF=5 mm/min

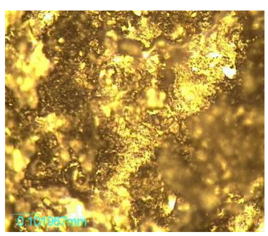

Fig. 2(j) WF=15 mm/min

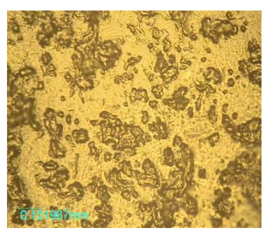

Fig. 2(k) WT=8 kgf

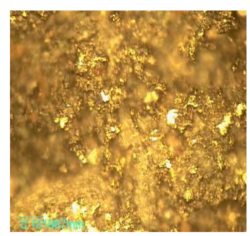

Fig. 2(l) WT=12 kgf

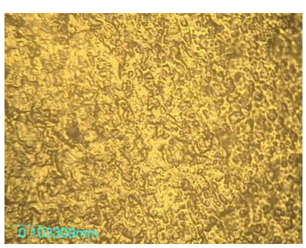

Fig. 2(m) SF=50

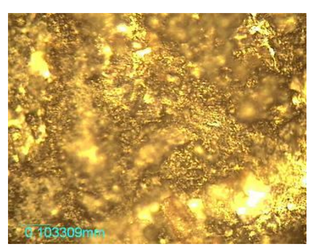

Fig. 2(n) SF=2050

Fig. 2 (a to n) Surface Topography of WEDM surface of Titanium alloy at different Test Conditions.

4. Conclusions

In this study, the influence of WEDM parameters such as pulse on time, pulse peak current, servo gap voltage, water pressure, wire feed rate, wire tension and server feed rate on surface roughness and surface topography have been studied. Based on the experimental results the following conclusions were made:

As the pulse on time or pulse duration, pulse peak current and servo feed rate increases the surface roughness was also increases. As the spark gap set voltage, water pressure, wire feed rate and wire tension increases the surface roughness decreases. However, for extended spark gap set voltage, water pressure, wire feed rate and wire tension, the surface roughness increases.

At higher pulse on time or pulse duration, pulse peak current and servo feed rate, the craters and the density of global appendages and pockmarks were high. Further, as the spark gap set voltage, water pressure, wire feed rate and wire tension increases the craters and the density of global appendages and pockmarks were low. However, for extended spark gap set voltage, water pressure, wire feed rate and wire tension, the craters and the density of global appendages and pockmarks were high.

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