Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 41 (2012) 1812 – 1817

Engineering Procedia

www.elsevier.com/locate/procedia

ELSEVIER

International Symposium on Robotics and Intelligent Sensors 2012 (IRIS 2012)

WEDM: INFLUENCE OF MACHINE FEED RATE IN MACHINING TITANIUM Ti-6Al-4V USING BRASS WIRE AND CONSTANT CURRENT (4A)

Aniza Alias[a], Bulan Abdullah[a]*, Norliana Mohd Abbas[a]

[a]Universiti Teknologi MARA,Shah Alam, 40450, Malaysia

Abstract

Wire electrical discharge machining (WEDM) technology has been widely used in tool and die-making industry, automotive, medical and practically any conductive materials. It is a non-traditional machining process which used the continuously circulating wire as electrode and cuts the workpiece along a programmed path. The aim of this paper is to investigate the influence of feed rate on the performance of WEDM on Titanium Ti-Al-4V. Brass wire was employed as the electrode in this study. The results on kerf width, material removal rate and surface roughness are graphically tabulated. The best combination of machining parameter viz. machine feed rate (4 mm/min), wire speed (8 m/min), wire tension (1.4kg) and voltage (60V) were identified. The selection of parameters depends on the requirements based on a better surface roughness or a maximum material removal rate. Hence an appropriate combination of variables can be selected accordingly. Furthermore, this combination can contributes to increase production rates perceptibly by reducing machining time.

Keywords: Wire Electrical Discharge Machining (WEDM), Titanium Ti-6Al-4V, Kerf Width, Matrial Removal Rate, Surface Roughness.

1. Introduction

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 [1]. However these alloys were very difficult to fabricate as they are not ductile and have low fracture toughness at room temperature [2]. Furthermore, due to its excellent strength property, it is found that it is extremely difficult to machine by conventional method. Several researchers [3, 4] 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. Hence, it is essential to introduce an alternative method in machining of this alloy.

Wire electrical discharge machining (WEDM) becomes an important non-traditional machining process due to its competency in machining of work pieces with complex geometry and hard stiffness [5]. The material is removed by a series of discrete electrical discharges between the wire electrode and the work piece in this process. 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. 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 [6]. Due to this reason, it has dramatically increased in high application of

* Corresponding author: Tel.: +60355435190; fax:+60355435160.
E-mail address: aliasaniza@gmail.com, bulanabdullah@gmail.com, lianabbas@gmail.com.

1877-7058 © 2012 Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
doi:10.1016/j.proeng.2012.07.388

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 [7, 8]. With improper of selecting parameters there are possibility of wire breakage imposes certain limits on the cutting speed, which in turn reduces productivity. The selection of optimum cutting parameters is solution in obtaining a higher cutting speed or good surface finish. However, even though with the up-to-date computer numerical control (CNC) WEDM machines exist, the problem of selecting optimum cutting parameters for WEDM processes is not fully solved. Machine feed rate, discharge current, wire speed, wire tension and average working voltage are the machining parameters which affect WEDM performance measures [9, 10].

This study aimed in achieving the appropriate conditions in machining Titanium Ti-6Al-4V resulted in term of kerf width, material removal rate (MRR) and surface roughness (Ra).

2. Materials and Method

2.1. Workpiece material

WEDM has tremendous potential on account of its versatility of application and its series of complex physical processes, including heating and cooling in non traditional machining processes [11]. But due to its complexity of the extraction process, difficulty of melting and problems during fabrication Titanium Ti-6Al-4V is expensive when compared to many other metals. By improving fabrication methods, it could result in reduced scrap losses and fabrication time, and thus reduced cost and increased availability [5]. Based on Y.F Luo [12], the electrical energy available for material removal is uniformly distributed along the length of the wire; therefore the material removal rate should not be affected by the material thickness. This study applied Titanium Ti-6Al-4V work piece with constant value of thickness (6mm) since only a few researcher done the studies regarding this material using WEDM.

2.2. Wire Electrode

Brass wire begun to be used in the late of the 1970s in WEDM machining. These conductive metal wires (diameter from 0.05mm to 0.35mm) are used in three-dimensional machining after programming the required shape and provide wires continuously. The most important properties to take into account are: (i) electric discharge performance; (ii) heat resistance; (iii) low calorification; and (iv) heat release [13].

2.3. Dielectric

Nowadays WEDM process is commonly conducted on work pieces that are totally submerged in a tank filled with dielectric fluid. This method grants temperature stabilization and efficient flushing especially when the work piece has varying thickness [5]. Due to its low viscosity and rapid cooling rate, WEDM uses deionised water instead of hydrocarbon oil as the dielectric fluid [14].

2.4. Parameter Setting

The process parameters such as machine feed rate, discharge current, wire speed, wire tension and average working voltage constantly affected the product quality produced by WEDM [9, 10]. In finding how the output parameter varies with the variation in the input parameter, three set of experiments as shown in Table 1 have been studied. All experiments were performed in constant current (4A) mode. The selection of factors was based on the journals, preliminary result and the suggestion from the handbook recommended by the machine manufacturer.

Table 1. WEDM Parameter Setting

Parameter	Experiment I	Experiment II	Experiment III
Machine Feed Rate (mm/min)	2	4	6
Current (A)	4	4	4
Wire Speed (m/min)	8	8	8
Wire Tension (kg)	1.4	1.4	1.4
Voltage (Volts)	60	60	60

2.5. Sample Preparation and Experimental Procedure

Before and after the machining, all specimens will be cleaned in an alcohol bath using Mini Ultrasonic Cleaner model MUC-100 and then dried using Beuhler Metaserv Specimen Dryer in blower mode. After that, the specimens will be kept in Buehler Specimen Cabinet Storage to prevent the formation of oxide on the surface. Titanium Ti-6Al-4V workpieces are cut into the desired size using Wirecut EDM Mitsubishi FX Series Machine (Figure 1) in the presence of dielectric fluid (deionized water) with addition of anti rust agent liquid to reduce the surface rust.

Fig. 1. Pictorial view of WEDM machine tool

The kerf is measured using the Infinite Focus Alicona Machine as the sum of the wire diameter and twice wire–workpiece gap. The kerf value was expressed in three different spot and each spot will give ten readings, the average of these reading will be taken as kerf width. The material removal rate (MRR) will be calculated using equation (1) this equation has been used by P.S. Rao et al. [14].

$$MRR = F \times D_w \times H \qquad (1)$$

Where F is the machine feed rate *[mm/min]*, D_w is wire diameter *[mm]* and H is piecework thickness *[mm]* and MRR is material removal rate *[mm^3 /min]*. After obtaining the experimental samples, surface roughness was measured using an Infinite Focus Alicona Machine on each piece work 3 times for achieving more accuracy and, subsequently, the average of it was selected. Stereo Zoom Microscope is used to see the macrostructure of machined surface (topography view). The results obtained will be represented in graphs and figures subsequently will be discussed.

3. Result and Analysis

3.1. Kerf Width

The graph from Figure 2 revealed about machine feed rate vs kerf width. Wire speed, wire tension and open voltage at constant while the machine feed rate varies. The lowest value of machine feed rate give smallest kerf width. Meanwhile, it can be seen clearly that medium setting of machine feed rate gives the average value of kerf width and high setting of machine feed rate applied offered the widest value of kerf width. This clarified the phenomenon that when the wire tension increased, it will reduce the wire vibration and resulted to smaller kerf width [15].

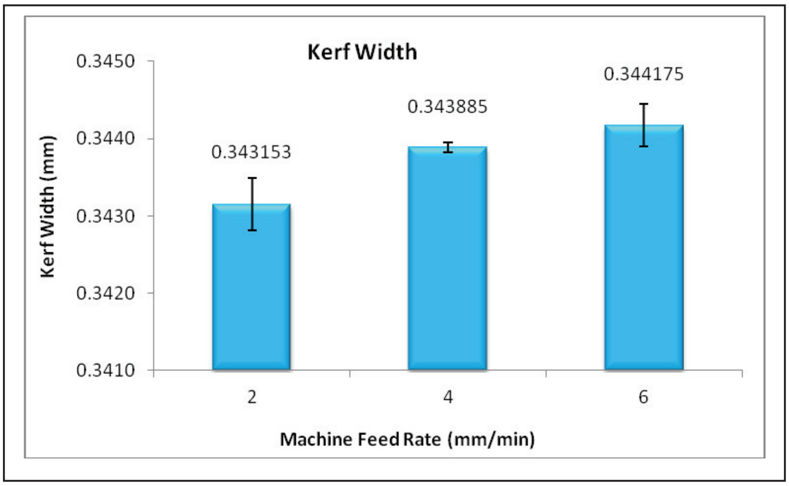

Fig. 2. Result on kerf width at different machine rate

3.2. Material Removal Rate (MRR)

Graph in Figure 3 shows the result where higher machine feed rate gives higher value of MRR and vice versa. Theoretically, material erosion is influenced by the spark energy. As feed rate increase; MRR also increases till it reaches optimum. Choice of MRR and surface roughness is also dependent on user and environment of the problem [16].

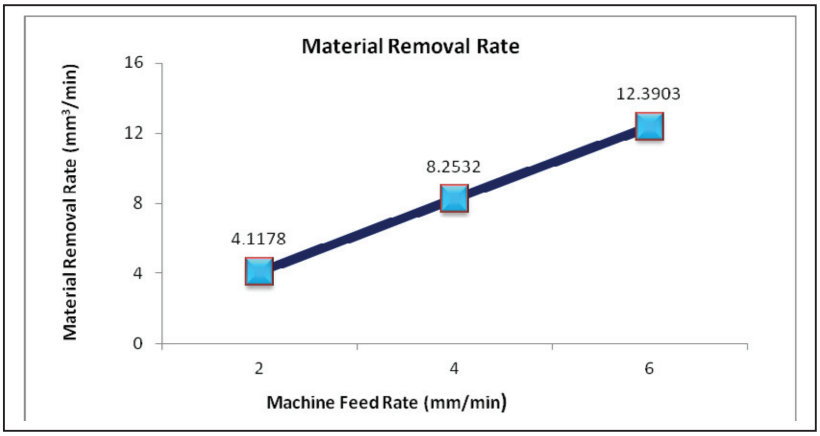

Fig. 3. Result on material removal rate at different machine rate

3.3. Surface Roughness (Ra)

Figure 3 discovered smoother surface which can be obtained at high machine feed rate. P.S. Rao et al. [15] explained that wire tension and spark gap voltage are significant parameters in obtaining better surface finish. By increasing wire tension, it reduces the vibration and improves the machined surface quality. The increase of voltage means that the electric field becomes stronger and the spark discharge takes place more easily under the same gap and a coarse surface is always obtained. Suleiman Abdulkareem et al. [18] has proved that wet WEDM can be used to improved surface roughness of titanium (Ti-6Al-4V) workpiece.

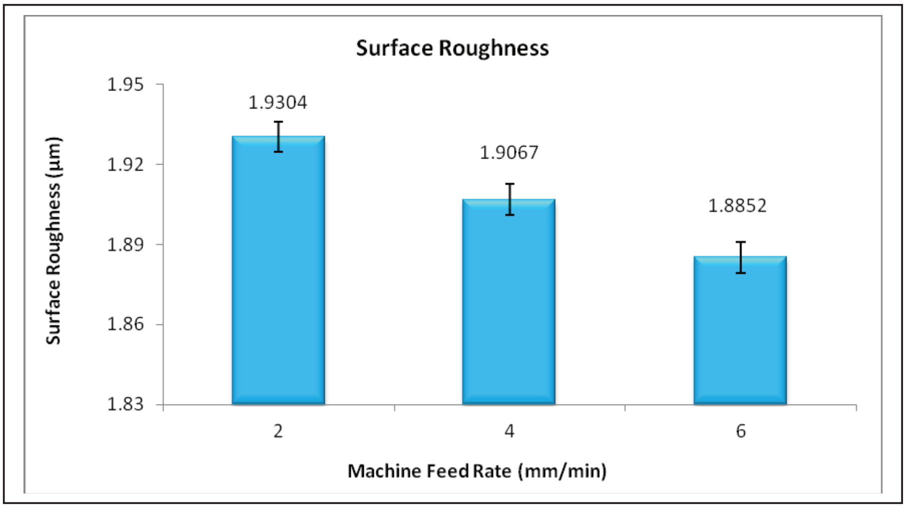

Fig. 4. Result on material removal rate at different machine rate

3.4. Surface Topography

There are many factors which make machined surface topography have the characteristics of complex and irregular, and impact using performance of parts due to its complicated process. Figure 5 shows the surface topography of each experiment under microscope with 100× magnification. It shows that low machine feed rate gives bigger crater compared to high feed rate and vice versa. Lei Geng and Huayan Zhong [19] 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. They also define Ra reflects the height information of the surface microscopic structure, and fractal dimension mainly shows the complex degree of surface topography, which reflects combined effect of surface spacing and the height and is independent of height characteristic and measurement scale.

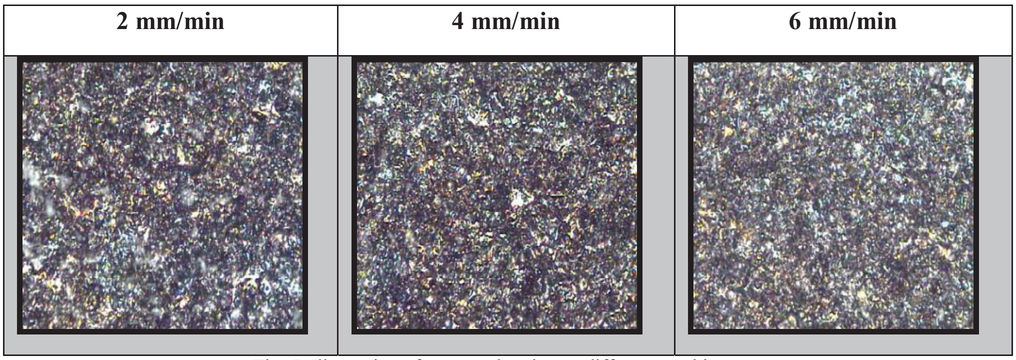

Fig. 5. Illustration of topography view at different machine rate

Conclusion

In this paper, an attempt was made to determine the important machining parameters for performance of WEDM viz. kerf width, MRR and Ra. The main goal is the maximum MRR with the minimum kerf and surface roughness in setting the machining parameters. Factors machine feed rate have been found to play an important role in this experimental work. The outcome of this study will help in improving the quality of Titanium Ti-6Al-4V products as well as minimizing the machining cost to realize the economical potential to the fullest.

Acknowledgements

The authors would like to acknowledge the support from the management and staffs in Faculty of Mechanical Engineering, UiTM, Shah Alam, Malaysia, are thanked for their contribution in respected area. And all those who contributed directly or indirectly are thanked.

References

[1] P. Kovacs, J. A. Davidson, in: S. A. Brown, J. E. Lemons (Eds.)., 1996, Medical Applications of Titanium and its Alloys: The Materials and Biological Issues, ASTM, STP 1272 pp. 163-178.
[2] B. Pan, D.J. Kim, B.M. Kim, T.A. Dean, 2001, Incremental deformation and the forgeability of titanium aluminide, Int. J. Mach. Tools Manuf. 41 749–759.
[3] A.R.C. Sharman, D.K. Aspinwall, R.C. Dewes, D. Clifton, P. Bowen, 2001, The effects of machined workpiece surface integrity on the fatigue life of titanium aluminide, Int. J. Mach. Tools Manuf. 41 1681–1685.
[4] D.F.Hasson, C.H.Hamilton, Forward, Editors: D. F. Hasson and C. H. Hamilton, 1982, Advanced Processing Methods for Titanium, the Metallurgical Society of AIME,
[5] K.H. Ho, S.T. Newman, S. Rahimifard, R.D. Allen, 2004, State of the art in wire electrical discharge machining (WEDM, International Journal of Machine Tools & Manufacture 44 1247–1259
[6] D. Rakwal and E. Bamberg, 2009, Slicing, Cleaning and Kerf Analysis of Germanium Wafers Machined by Wire Electrical Discharge Machining, J. Mater. Process. Technol, 209(8), p 3740–3751
[7] Sarkar S, Sekh M, Mitra S, Bhattacharyya B., 2008, Modeling and optimization of wire electrical discharge machining of γ-TiAl in trim cutting operation. J Mater Process Technol 205(1–3):376–387
[8] Garg RK, Singh KK, Sachdeva A, Sharma VS, Ojha K, Singh S., 2010,
Review of research work in sinking EDM and WEDM on metal matrix composite materials. Int J Adv Manuf Technol 50(5–8):611–624
[9] Gauri SK, Chakraborty S., 2010, A study on the performance of some multi-response optimisation methods for WEDM processes. Int J Adv Manuf Technol 49(1–4):155–166
[10] Rao RV, Pawar PJ., 2009, Modelling and optimization of process parameters of wire electrical discharge machining. Proc IME B J Eng Manuf 223(11):1431–1440
[11] Anish Kumar, Vinod Kumar and Jatinder Kumar 3, 2012, An Investigation into Machining Characteristics of Commercially Pure Titanium (Grade-2) using CNC WEDM Applied Mechanics and Materials Vol. 159 pp 56-68 Trans Tech Publications, Switzerland
[12] Y.F. Luo, 1995, Energy-Distribution Strategy in Fast-Cutting Wire EDM, J. Mater. Process. Technol, 55(3–4), p 380–390
[13] Seigi Aoyama, 2001, Development of High Performance Wire Electrode for Wire Electric Discharge Machining, Journal of Japan Society of Electrical Machining Engineers, Vol.35, No.79
[14] Pujari Srinivasa Rao, Dr. Koona Ramji And Prof. Beela Satyanarayan, 2010, A Prediction of Material removal rate for Aluminum BIS-24345 Alloy in wire-cut EDM, International Journal of Engineering Science and Technology Vol. 2 (12), , 7729-7739
[15] C.T. Lin, I.F. Chung, and S.Y. Huang, 2001, Improvement of Machining Accuracy by Fuzzy Logic at Corner Parts for Wire-EDM, Fuzzy Sets Syst, 122(3), p 499–511
[16] Abolfazl Golshan, Soheil Gohari, and Amran Ayob, Computational Intelligence in Optimization of Wire Electrical Discharge Machining of Cold-Work Steel 2601 International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS Vol: 11 No: 04.
[17] K. Palanikumar, B. Latha , V.S.Senthilkumar ,R.Karthikeyan, 2009, Multiple Performance Optimization in Machining of GFRP Composites by a PCD Tool using Non-dominated Sorting Genetic Algorithm (NSGAII), Met. Mater. Int., Vol.15, No.2, pp.249~258,
[18] Suleiman Abdulkareem, Ahsan Ali Khan and Zakaria Mohd Zain, 2011, Experimental Investigation Of Machining Parameters On Surface Roughness In Dry And Wet Wire-Electrical Discharge Machining, Advanced Materials Research Vols. 264-265 (2011) pp 831-836
[19] Lei Geng, Huayan Zhong ,2010, Evaluation of WEDM Surface Quality Advanced Materials Research Vols. 97-101 pp 4080-4083