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Review on Wire Electric Discharge Machining Process of Titanium Alloy

M. Mahalingam
Department of Manufacturing Engineering, Annamalai University, Annamalainagar, Tamilnadu, India

ABSTRACT

Wire electro- discharge machining (WEDM) is known as unique cutting in manufacturing industries, especially in the good tolerance with intricate shape geometry in die industry. Titanium material is widely used in aerospace industries. This titanium material has excellent resistance to high temperature, mechanical and chemical degradations with toughness and work hardening characteristics materials. Due to these properties, the machinability studies of this material have been carried-out in this study. The aim of this review paper is to present the consolidated information on processing of Titanium material using electrical discharge machining (EDM) and wire electrical discharge machining process (WEDM) and subsequently identify the research gaps.

Keywords : EDM, WEDM, Titanium alloy, Process parameters, Review

I. INTRODUCTION

The use of titanium and titanium alloys in recent years has increased significantly due to the development of methods related to their production, further processing and their advantages over other materials. Titanium is a very strong and light metal with excellent corrosion resistance, fatigue resistance, a high strength-to weight ratio that is maintained at elevated temperature. Titanium and its alloys are attractive and important materials in modern industry due to their unique properties that are mentioned [1, 2].

Titanium and its alloys are used in many different industries such as biomedical applications, automobile, aerospace, chemical field, electronic, gas and food industry [6]. The application of these materials in various fields of automotive industry such as spring suspension, bumper, exhaust valves, connecting rods and many other applications. The application of these materials in various fields of aircraft industry such as Cockpit window frame, Wing box, Fastener, Hydraulic pipe, Landing gear, Track beam, Exhaust, Tail cone, Duct. Titanium is used in different medical applications such as dental implants, hip and knee prostheses, trauma-fixing equipment (nails, screws), medical instruments, heart valves, pacemakers and many other applications. On the other hand, there is some limitation for titanium use because of its initial high cost, availability, inherent properties and manufacturability [9]. Machining titanium and its alloys by conventional machining methods has some difficulties such as high cutting temperature and high tool wear ratio. Thus, titanium and its alloys are classified as difficult-to-machine materials. Therefore, unconventional machining processes are introduced for machining titanium and its alloys [2, 6].

The review presented in this paper is on the Electrical Discharge Machining & wire EDM process on Titanium material widely used in many applications including aeronautics and automotive industry. Where this material is required to retain high strength and corrosion resistance.

In this paper description of various process parameters and their responses have been presented. Finally the suggestions for future researcher have been outlined.

II. LITERATURE SURVEY OF WIRE ELECTRIC DISCHARGE MACHINING ON TITANIUM AND ITS ALLOYS

Antar et al.,[1], studied about the workpiece productivity and integrity of machining Udimet 720 nickel based super alloy and Ti-6Al-2Sn4Zr-6Mo titanium alloy, using Cu core coated wires (ZnCu50 and Zn rich brass). It was found that up to a 40% for Udimet 720 and 70% for Ti- 6Al-2Sn4Zr-6Mo titanium alloy increase in productivity was possible compared to when using uncoated brass wires with the same operating parameters.

Aniza Alias et al., [2], investigated the influence of feed rate on the performance of WEDM on Titanium Ti-Al-4V. Brass wire was used as the electrode. The best combination of machining parameter was identified as machine feed rate (4 mm/min), wire speed (8 m/min), wire tension (1.4kg) and voltage (60V). The outcome of this study to help in improving the quality of Titanium Ti-6Al-4V products as well as minimizing the machining cost to realize the economic potential to the fullest.

Anish Kumar et al., [3], investigated on the Metallographic Analysis of Pure Titanium (Grade-2)Surface by Wire Electro Discharge Machining(WEDM) and conclude that surface produces the more irregular topography and defects included globules of debris, spherical particles, craters, pockmarks and micro-cracks. The pulse on time and peak current are the most significant parameters which lead to deteriorate the surface texture. The residuals of copper, carbon and zinc were detected in the machined samples using EDX analysis. This may be due to the melting, evaporation and re-solidification of the brass wire electrode and are transferred to the work material.

Anish Kumar et al., [4], investigated on the effect of Wire Breakage Frequency in WEDM process of Pure Titanium and conclude that the wire breakage frequency continuously increases with an increase in pulse on time. When the value of pulse on time is minimum then there is no wire breakage, but as the pulse on time increases, the probability of wire breakage starts increasing due to increase of discharge rate. Due to increase of pulse on time the rate of discharge energy increases which may significant affect wire breakage frequency.

Aspinwall et al., [5], discussed machining of Ti-6Al-4V and Inconel-718 using two high specification WEDM machines with pulse generators designed to provide minimum work piece integrity damage. Operating parameters were selected to provide target work piece surface roughness values for all occurred cuts. Consequently, the cut surfaces were analyzed for exploring any change in micro hardness and micro structure. Results of analysis revealed that the thickness of average recast layer obtained was less than 11μm and several trim passes showed no apparent recast or damage.

Chen, et al., [6], The MRR varies with dielectric fluid usage, when using deionized water as dielectric the MRR increases linearly with the pulse on duration. When kerosene is used as dielectric fluid, MRR increases till the optimum point and further reduces. In addition the electrode wear ratio (EWR) increases with the pulse on time duration but when using deionized water the EWR is relatively less compared with the kerosene.

Danial Ghodsiyeh et al., [7], studied the effect of machining parameters including pulse on time, pulse off time, and peak current on surface roughness, sparking gap and material removal rate of titanium (Ti6Al4V). Statically optimization model (a central composite design coupled with response surface methodology overcomes the limitations of classical methods and was successfully employed to obtain the optimum processing conditions while the interactions between process variables were demonstrated.

Gu et al., [8], studied the EDM of Ti-6Al-4V alloy with the bundle die sinking electrode and performance compared with the solid die sinking electrode. During machining with both the electrodes, MRR increases with the increase in peak current. The more carbon particles were deposited on the solid electrode surface than the bundle electrode. The gap diminishes the insulation effect of the dielectric medium leading to unstable discharge because of limited flushing.

Hascalik and caydas [9], studied the surface integrity property of Ti6Al4V alloy by EDM and abrasive electrochemical grinding (AECG). The damages which has occur by EDM can be reduced by the AECG and to achieve good surface finish.

Harcuba et al., [10], investigated on the biocompatibility of Ti6Al4V alloy after the surface machining by the electric discharge machining (EDM) process.

The surface modification considered to be promising improvement to orthopedic implants and bone tissues. In this context, the survey is made on responses of machining of Ti based alloys and the statistical techniques used to correlate the experimental study.

Hseigh et al., [11], investigated WEDM characteristics of Ti-Ni-X ternary shape memory alloys. Experimental results showed that maximum feed rate without wire breakage of wire electrode for Ti35.5Ni49.5Zr15 and Ti50Ni49.5Cr0.5 alloys in WEDM process exhibited a reverse relationship with product of alloy's melting temperature and thermal conductivity.

Kao et al., [12], optimized the EDM process parameters on EWR, MRR and surface roughness of Ti6Al4V alloy using Taguchi and grey relation technique.

Klocke et al., [13], investigated on the fatigue strength and surface property of EDMed Ti6Al4V alloy. The EDMed specimen has better fatigue life compared to grinding.

Kuriakose and Shunmugam [14], investigated the effects of different parameters on surface characteristics of Ti6Al4V. It is observed that more uniform surface characteristics are obtained with coated wire electrode.

Kuriachen Basil et al., [15], investigated the effect of voltage, dielectric pressure, pulse on-time and pulse off-time on spark gap of Ti6Al4V alloy. It has been found that pulse on time and pulse off time have the more impact on the spark gap. In this experimental study two level full factorial experiment is adopted because this gives all possible combinations of machine parameters. It can be noticed that corresponding to minimum value of pulse off time the spark gap decreases with increase in dielectric pressure, whereas the spark gap increases with increase in dielectric pressure corresponding to maximum value of pulse off time.

Liao and Yu., [16], introduced a term named as specific discharge energy (SDE), which is real energy required removing a unit volume of material. Specific discharge energies of different materials were compared and then materials having close value of SDE such as Ti-6Al-4V, stainless steel and Inconel 718 were selected. Their machinability characteristics under identical machining conditions were evaluated and compared. A quantitative relationship between machining characteristics and machining parameters was obtained through dimensional analysis. Experimental results indicated that materials having close values of SDE demonstrated very close machining characteristics such as machining speed, groove width and surface finish of machined surface under same machining conditions.

Lin et al., [17], investigated the MRR for combined EDM with USM of Ti6Al4V alloy by using the kerosene and deionized water with SiC abrasive concentration as dielectrics. Thus the abrasive enhances the gap between the electrode and work-piece causes higher MRR.

Miller et al., [18],investigated the Effects of WEDM process parameters, particularly the spark cycle time and spark on time on thin cross section cutting of Nd-Fe-B magnetic material, carbon bipolar plate and pure titanium were investigated. The study generated an envelope of feasible wire EDM process parameters for commercially pure titanium which can be utilized for production of micro features on Ti components. Scanning electron microscopy observations of EDMed surface, subsurface and debris lead to a hypothesis, to explain the limiting factor for wire EDM cutting of thin sections based upon the thermal and electrostatic stress induced fracture in the test pieces.

Pasam et al., [19], experimentally investigated the WEDM of titanium alloy (Ti6Al4V). The behavior of eight control parameters such as Ignition pulse current (A), Short pulse duration(B), Time between two pulses(C), Servo speed(D), Servo reference voltage(E), Injection pressure(F), Wire speed(G) and Wire tension(H) on surface finish was studied using Taguchi parameter design. A mathematical model was developed by means of linear regression analysis to establish relationship between control parameters and surface finish as process response.

Peng et al., [20], The nanostructured oxide layer formed during the EDM increases the biocompatiability of the titanium material.

Poros and Zoboruski., [21], investigated volumetric efficiency in WEDM of Ti6Al4V taking into consideration both process parameters (discharge time and working voltage) and material properties (melting point, electrical conductivity, thermal expansion, density and heat capacity of work piece).

Qin et al., [22], reported wire EDM cutting induced hydride precipitation in surface layer of Ti-46Al-2Cr alloy. The existence of hydride in surface layer of TiAl intermetallic alloys play a detrimental role in determining their mechanical properties if hydride layer is not carefully removed. This hydride layer has a poor thermal stability as other titanium hydrides and was removed by vacuum annealing at 400-600ºC.

Sarkar et al., [23], studied wire electric discharge machining of γ titanium alumnide (γ-Ti Al) alloy. A feed forward back propagation neural network model was developed to predict the response parameters namely cutting speed, surface roughness and wire offset as a function of six different control parameters viz. pulse on time, pulse off time, peak current, wire tension, dielectric flow rate and servo reference voltage. Twenty seven optimum parametric combinations were presented which can be utilized as technology guidelines for effective machining of this alloy. Experimental results demonstrated that machining model is suitable to satisfy the practical machining requirements.

Sarkar et al., [24], investigated modeling and optimization of wire electrical discharge machining of γ-TiAl in trim cutting operation. A second-order mathematical model, in terms of machining parameters, was developed for surface roughness, dimensional shift and cutting speed using response surface methodology (RSM). The experimental plan was based on face centered, central composite design (CCD). The trim cutting operation was optimized for a given machining condition by desirability function approach and Pareto optimization algorithm. The residual analysis and experimental results indicated that the proposed models could adequately describe the performance indicators within the limits of the factors that are being investigated.

Sarkar et al., [25], studied the influence of process parameters on cutting speed and surface roughness. Pareto optimization was applied to determine the maximum cutting speed corresponding to the required surface roughness for trim cutting process. By combining results of single and multi-pass cutting a machining strategy based upon the novel concept of critical surface roughness was developed for selecting the machining process parameters.

Yilmaz and Okka [26] studied the effect of single and multi-channel electrodes on MRR made of copper and brass materials. The single channel copper electrode has higher MRR compared to multichannel copper and brass electrode. Brass electrode is more efficient to obtain higher MRR because of low thermal conductivity and does not absorb much heat.

III. CONCLUSION

This paper has presented significant contributions of the researches on EDM and WEDM on Titanium materials and its alloys. The study of this paper reveals the research gaps, which may be useful for carrying out research by future researchers.

The researchers have interestingly studied and presented their investigation on the important aspects of machined properties of advanced materials affected by the input parameters and other constituents. It is also clear that, Limited work has been reported on the machining of Ti-6Al-4V alloy using WEDM.

The literature survey reported in this paper revealed that, researchers are concentrating on many machining parameters. However, the study of surface integrity of the Ti-6Al-4V has not been investigated by many researchers. In this background, the research gaps identified in this paper indicate that, there is a scope for future researchers for investigation.

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