International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 04, April-2017

Electric Discharge Machining (EDM) of Titanium Alloys: A Review

V. S. Nimbalkar
Department of Mechanical Engineering
Government College of Engineering,
Amravati, Maharashtra, India

Prof. M. T. Shete
Department of Mechanical Engineering
Government College of Engineering,
Amravati, Maharashtra, India

Abstract **- Electrical discharge machining (EDM) is one of the earliest non-traditional machining processes. This process is based on thermoelectric energy between the workpiece and an electrode. Electrical discharge machining is basically a non-conventional material removal process. This process is widely used to produce dies, punches and moulds, finishing parts for aerospace and automotive industry, and surgical components. Irrespective of their hardness, shape and toughness, this process can be successfully employed to machine electrically conductive parts. Titanium alloys are of an increasing importance in engineering applications because of their excellent combination of high strength, low density and corrosion resistance. Titanium alloy has wide applications in field of aerospace, automotive, nuclear, chemical, marine and biomedical industries. This paper presents a review on EDM for titanium alloy and future applications.**

Index Terms - Electrical Discharge Machining, Titanium alloy, Material Removal Rate(MRR),Surface Roughness(SR),Tool Wear Rate(TWR).

I. INTRODUCTION

In the late 1940s Electrical discharge machining (EDM) technique was developed where the process of removing material from a part is by means of a series of repeated electrical discharges between tool called the electrode and the work piece in the presence of a dielectric fluid. The electrode is moved toward the work piece until the gap is small enough so that the impressed voltage is great enough to ionize the dielectric. Short duration discharges are generated in a liquid dielectric gap, which separates tool and work piece. The material is removed with the erosive effect of the electrical discharges from tool and work piece. EDM does not make direct contact between the electrode and the work piece where it can eliminate mechanical stresses, chatter and vibration problems during machining. Materials of any hardness can be cut as long as the material can conduct electricity. Any type of conductive material can be machined using EDM irrespective of the hardness or toughness of the material.

Importance of Titanium alloys in engineering applications is increasing because of their excellent combination of high strength, low density and corrosion resistance. They have wide applications in aerospace, automotive, nuclear, chemical, marine and biomedical industries. Titanium alloys are known to possess poor wear resistance that restricts its applications particularly in areas involving wear and friction. The scope of the applications for titanium alloys has been somewhat impeded owing to poor wear resistance under abrasion and erosion conditions[6].

II. EDM PROCESS PARAMETERS

The process parameters that influence while electric discharge machining are listed below:

i)Discharge current - It points out the different levels of power that can be supplied by the generator of the EDM machine and represents the mean value of the discharge current intensity.

ii)Pulse-on time - It is the duration of time (μs) the current is allowed to flow per cycle. Material removal is directly proportional to the amount of energy applied during this pulse-on time. This energy is controlled by the discharge current and the duration of the pulse-on time.

iii)Pulse-off time - It is the duration of time (μs) between the two successive sparks (pulse-on time). This time allows the molten material to solidify and to be wash out of the arc gap. This parameter is to affect the speed and the stability of the cut. Thus, if the off-time is too short, it will cause sparks to be unstable.

iv)Duty cycle - It is a percentage of the pulse-on time relative to the total cycle time. This parameter is calculated by dividing the pulse-on time by the total cycle time (pulse-on time plus pulse-off time). The result is multiplied by 100 for the percentage of efficiency, called duty cycle.

v)Dielectric pressure - This is the flushing pressure of the dielectric jet which removes the chip or debris produced during the EDM process away from the gap zone. This value of pressure is measured by pressure gauge existing in the EDM machine.

vi)Polarity - The machine can run either in normal polarity or reverse polarity.The polarity normally used is straight (normal polarity) in which the tool is negative and work piece is positive, while in reverse polarity the tool is positive and work piece is negative.

The effectiveness of EDM process is evaluated in terms of its machining characteristics. The short product development cycles and growing cost pressures have forced the die and mould making industries to increase the EDM efficiency. The EDM efficiency is measured in terms of its machining characteristics viz. material removal rate, surface roughness and tool wear rate. The most important machining characteristics considered in the present work are:

i)Surface Roughness (R_a): Surface finish is an essential requirement in determining the surface quality of a product. The average surface roughness is the integral absolute value of the height of the roughness profile over the evaluation length (L) and was represented by the equation given below.

$$R_a = \frac{1}{L}\int_0^L |Y(x)dx$$

Where 'L' is the length taken for observation and 'Y' is the ordinate of the profile curve.

ii)Material removal rate (MRR): Material removal rate is a desirable characteristic and it should be as high as possible to give least machine cycle time leading to increased productivity. Material removal is the difference of weight of work-piece before machining and after machining. It is calculated by the formula as given below.

$$MRR = \frac{W_i - W_f}{\rho_w t} \text{ mm}^3/\text{ min}$$

Where, W_i is the initial weight of work-piece in g; W_f is the final weight of work-piece after machining in g; t is the machining time in minutes and ρ_w is the density of work piece material.

iii)Tool Wear Rate (TWR):Tool wear rate is the difference of electrode weight before and after machining and is expressed as:

$$TWR = \frac{E_i - E_f}{\rho_e \ t} \text{ mm}^3/\text{min}$$

Where, E_i is the initial weight of electrode in g; E_f is the final weight of electrode after machining in g; t is the machining time in minutes and ρ_e is the density of electrode material.

III. LITERATURE SURVEY

Anoop Kumar Singh ,Sanjeev Kumar ,V.P Singh [1] studied electrical discharge machining of superalloys and its future applications . The past two decades has seen the increasing use of EDM on superalloys. The process has resulted in a significant improvement in complex machining problems in difficult-to-cut alloys. The application of EDM process in the machining of nickel base and titanium base alloys has addressed the surface integrity, metallurgical states and topological parameters. Many features still need to be addressed for the positive impact of the process on the industry. The use of electrode material in the machining process of superalloys was limited to only few where as there is a scope for using powder metallurgy and composite electrodes for better results in material transfer.The research as surface modification using powders in dielectric is the another area of importance to be studied, as so far the use of only Gr, Al, SiC and B4C powders has beenreported other material powders can also be tried. Various research works has been carried out considering the effect of discharge current and pulse duration where as there is a need to study the pulse off-time also for considering white layer and surface topography.

J. P. Nobre, J. C. Outeiro [2] evaluated the residual stresses induced by drilling Ti-6Al-4V alloy. An experimental-numerical methodology is applied to evaluate the residual stresses induced by drilling of Ti-6Al-4V alloy. The influence of ultra-high cutting speeds on the residual stress distribution is analysed. These ultra-high cutting speeds are produced by a turbine system powered by compressed air, which are commonly used in the hole-drilling equipment for residual stress measurements. The applied hybrid methodology has demonstrated an important role on the optimization of the drilling operations parameters for an improved residual stress distribution.

A. T. Bozdana O. Yilmaz, M. A. Okka .I .H. Filiz [3] presented a comparative experimental study on machining and surface characteristics of through and blind holes (Ø1 mm) produced on aerospace alloys of Ti-6Al-4V and Inconel 718 by fast hole rotary EDM process using tubular hollow copper and brass electrodes. Several holes were produced using the identical process parameters, and the corresponding values of Material Removal Rate (MRR) and Electrode Wear (EW) were compared. Surface characteristics of machined hole surfaces were also evaluated based on micrographs obtained by Scanning Electron Microscopy (SEM). The results reveal that the achievement of desirable MRR and EW values and acceptable topography of machined surfaces were dependent upon the appropriate selection of tool electrode material and the choice of making through/blind hole.

Mitali Mhatre. Sagar U. Sapkal And Raju S. Pawade[4], presented work on grey relational theory based parameter optimisation in Electric discharge machining (EDM) of Ti-6Al-4V.The multiple responses optimized are MRR, TWR and surface roughness. Results revealed that the copper electrode gives optimum performance in terms of higher MRR and lower TWR and SR.

A. W. S. Ram. Prasad, Koona, Ramji, G. L. Dutta[5], investigated effect of machining parameters on material removal rate and surface roughness in WEDM operations for Ti-6Al-4V.experiments were performed to study the performance characteristics using taguchi method. Based on investigation both significant parameters on both MRR and R_a was found to be peak current and pulse on time .pulse off time and servo voltage were least effective factors.

*Goutam Devaraya Revankar, Raviraj Shetty , Shrikantha Srinivas Rao ,Vinayak Neelakanth Gaitonde[6]*studied to improve the wear resistance of titanium alloys by ball burnishing process. The optimization results showed that specific wear rate decreased by 52%, whereas coefficient of friction was reduced by 64% as compared to the turned surface. Taguchi optimization results revealed that burnishing force and number of pass were the significant parameters for minimizing the specific wear rate, whereas the burnishing feed and speed play important roles in minimizing the coefficient of friction. After burnishing surface microhardness increased from 340 to 405 Hv, surface roughness decreased from 0.45 to 0.12 m and compressive residual stress were generated immediately below the burnished surface.

Apiwat Muttamara[7], carried out an experiment on Ti6Al4V.Performance with respect to MRR and electrode wear was compared for two graphite qualities. The results showed that EDM3 graphite performs very well giving significantly higher MRR than EDM-C3, and also with acceptable relative electrode wear. The surface roughness of workpiece produced by EDM-C3 is better than EDM-3 due to gap distance of EDM-C3 is larger than that produced by EDM-3. The two electrode materials give the same micro-hardness of the layers that are about 800 HV.

Saeed Daneshmand,Ehsan Farahmand Kharizi,Esmail Abedi,M.Mir Abdolhosseini[8], study the effects of electro discharge machining parameters such as voltage, discharge current, pulse on time and pulse off time on the rate of material removal, tool wear, relative electrode wear and surface roughness of NiTi alloy. For the design of experiments, the Taguchi's method for the design of experiments, L18 orthogonal array and the 'Minitab' software program have been used. The experiments indicate that the parameters of discharge current, voltage, and pulse on time have a direct impact on material removal rate (MRR), and with their increase, MRR increases as well. Tool wear rate (TWR) diminishes with the increase of pulse off time and discharge current. The analysis of results obtained for surface roughness indicates that pulse on time and off time have the highest impact on the surface roughness of NiTi alloy.

IV.CONCLUSION

This article presents a review of research work carried out in the determination and optimization of the process parameters for EDM. A number of research works based on various optimization techniques were reviewed including RSM, Taguchi method. A review of research work on various optimization techniques indicated that there were successful industrial applications of Taguchi method, RSM. These are robust optimization techniques to make experimental design insensitive to uncontrollable factors such as environmental parameters to predict responses and optimize the EDM process conditions in accuracy level. Various research has been carried out on titanium alloys .There is scope of research on titanium alloys using advance EDM

REFERENCES

[1] Anoop Kumar Singh ,Sanjeev Kumar ,V.P Singh ,Electrical Discharge Machining Of Superalloys :A Review ,IJRMET Vol 3,Issue 2 ,May-Oct 2013 |ISSN : 2249-5762|

[2] J.P.Nobre ,J.C.Outeiro ,Evaluating Residual Stresses Induced By Drilling Of Ti-6Al-4V Alloy By Using Experimental-Numerical Methodology ,15th CIRP Conference on Modelling of Machining Operations ,Procedia CIRP 31 (2015) 215-220

[3] A.T.Bozdana O.Yilmaz,M.A..Okka.I.H.Filiz ,A Comparative Experimental Study On Fast Hole EDM Of Inconel 718 And Ti-6Al-4v,5th international conference and exhibition on design and production of machines and dies and moulds.18-21 June 2009.

[4] Mitali Mhatre.Sagar U.Sapkal And Raju S.Pawade ,Electro Discharge Machining Characteristics Of Ti-6Al-4v Alloy:A Grey Relational Optimization ,International Conference On Advances In Manufacturing And Materials Engineering.AMME 2014,Procedia Materials Science 5 (2014)2014-2022.

[5] A.W.S.Ram.Prasad,Koona Ramji,G.L.Dutta,An Experimental Study Of Wire EDM On Ti-6Al-4V Alloy, International Conference On Advances In Manufacturing And Materials Engineering.AMME 2014,Procedia Materials Science 5 (2014)2567-2576.

[6] Goutam Devaraya Revankar, Raviraj Shetty, Shrikantha Srinivas Rao ,Vinayak Neelakanth Gaitonde ,Wear resistance enhancement of titanium alloy(Ti–6Al–4V) by ball burnishing process,JMRTEC-212.

[7] Apiwat Muttamara, Comparison Performances of EDM on Ti6Al4V with Two Graphite Grades, International Journal of Chemical Engineering and Applications, Vol. 6, No. 4, August 2015.

[8] SaeedDaneshmand,Ehsan Farahmand Kharizi,Esmail Abedi,M.Mir Abdolhosseini ; Influence Of Machining Parameters On Electro Discharge Machining Of Niti Shape Memory Alloys ,Int.J.Lectrochem.Sci.,8(2013) 3095-3104.