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Characterization of process parameters for drilling of holes on titanium using drill EDM

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Abstract

Material removing rate is an important parameter to judge the machine capability. The surface generated due to material removal should also meet the required surface finish and surface integrity, and geometrical dimensional accuracies. EDM (Electro discharge machining) is a process in which material is removed to obtain desired shape by process of discharge of spark between tool and workpiece. The important process parameters related to EDM are pulse on time, current, voltage. The objective here is to drill small holes using drill EDM and optimizing the process parameters by using Taguchi design methodology. The performance characteristics in machining Titanium work material by drill EDM are optimized. The three parameters are varied to obtain results which have significant effects on the drilled holes. The drilled holes will be evaluated by the output parameters such as surface roughness. The input process parameters will be analyzed by ANOVA method, and evaluated by mini tab software to determine optimum parameters.

Keywords: *Titanium, EDM process, Taguchi method, Anova, Mini tab.*

1. Introduction

Electrical discharge machining (EDM) is a process in which material removal is obtained by sparks between electrode and workpiece, with includes melting and vaporization caused by high temperatures. The workpiece and the electrode are overspread in a dielectric fluid and are connected to a generator delivering periodic pulses of energy.

There is no contact between the workpiece and the electrode and the small gap separating them is maintained under servo control. There are different processes of EDM processes includes die sink EDM, wire EDM and EDM fast hole drilling. The main variation between fast hole drilling and other processes lies in the use of a high pressure (70 – 100 bar) dielectric pump.

The combination of the high pressure dielectric fluid, the rotation of the tubular electrode and the high electrode feed rate (controlled by a fast response servo) make it possible to produce holes at a very fast rate. Drilling rates up to 1mm/second can be done and hole sizes are generally between 0.3 and 3mm, with a length-to-diameter ratio of over 150:1. This process can be adopted in the production of different parts which includes fuel injectors, cutting tools, medical equipment and aerospace components. EDM fast hole drilling has good importance in the aerospace industry. It is one of the few manufacturing processes that can be applied to the drilling of precision small holes in a number of parts, including turbine blades.

One of the most important factors which shows the impact of speed EDM hole drilling is the high pressure dielectric fluid which is supplied to the gap through the bore of tubular electrodes. Thus, it can be expected that the bore size and geometry have a great impact on the process performance. EDM performance also depends on a number of other factors including the generator (electrical parameters) and on a very complex relationship among these parameters, electrode geometry and dielectric flushing. Under such circumstances, optimal results can be obtained with the application of statistical methods such as response surface design. In this project the interest is towards the final surface roughness values gained. Surface roughness often shortened to roughness, is a component of surface appearance. It is specified by the difference in the direction of the normal vector of a real surface from its ideal form.

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If these differences are large, the surface is uneven; if they are small, the surface is even. Roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface. Although a high roughness value is often not accepted, it can be difficult and expensive to control in manufacturing. Lowering the roughness of a surface will usually increase its manufacturing costs. This often results in a trade-off between the manufacturing cost of a component and its performance in application. Roughness can be measured by manual comparison against a "surface roughness comparator", a sample of known surface roughness's, but more generally a surface profile measurement is made with a profilometer that can be contact (typically a diamond stylus) or optical (e.g. a white light interferometer or laser scanning confocal microscope).
Electric Discharge machining (EDM) is a thermo-electrical process used to machine very effective and tricky shapes on the hard metals such as ceramics, maraging steels, cast-alloys, titanium which are widely used in defense and aerospace industries. Electrical energy is used to generate electrical sparks and material removal mainly occurs due to localized melting and vaporization of material which is carried away by the dielectric fluid flow between the electrodes. The performance of this process is mainly motivated by many electrical parameters like, current, voltage, polarity, and pulse on time, pulse of time, electrode gap and also on non-electrical parameters like work and tool material, dielectric fluid pressure.

2. Characteristics of Titanium

Titanium is a chemical element with symbol Ti and atomic number 22. It is a transition metal with a silver color, low density and high strength. It is highly resistant to corrosion in sea water, aqua regia, and chlorine. Titanium was discovered in Cornwall, Great Britain, by William Gregor in 1791. The element occurs within a number of mineral deposits, which are widely distributed in the Earth's crust and lithosphere, and it is found in almost all living things, rocks, water bodies, and soils. The metal is pulled from its principal mineral ores by the kroll and hunter processes. It is a strong metal with low density that is ductile and the relatively high melting point (more than 1,650 °C).It is paramagnetic and has low electrical and thermal conductivity.

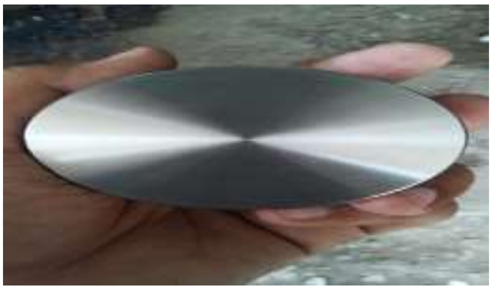

Fig1 Titanium specimen

Table1 Chemical composition

S. NO	COMPOSITION	WT%
1	C	Max 0.1
2	Fe	Max 0.3
3	H	Max 0.015
4	N	Max 0.03
5	O	Max 0.25
6	Ti	99.2

Experimental work

Taguchi experimental design is used for settings of drilling parameters to be determined. Orthogonal arrays of Taguchi, the Signal – to– Noise (S/N) ratio, the analysis of variance (ANOVA), and regression analysis are engaged to analyse the effect of the drilling parameters on surface roughness, hole diameter error values. In order to minimize time and cost, experiments are carried out using L9 orthogonal array. For the purpose of observing the degree of influence of the cutting conditions in drilling process three factors (current, pulse on time and drill diameter), each at three levels are taken into account.

Experimental Set Up

EDM drilling is well known in the field of manufacturing metal pieces with complex geometries. It has great applications like drilling holes in turbine blades, fuel injectors, cutting tool for coolant, hardened punch ejector. It is also used to remove broken tools in small holes, making plastic mold vent holes, wire EDM starter holes, mini machines/robots and air vent holes for forging dies. The same can be utilized for dovetail finger pin removal, cross key pin removal, balance hole drilling, removal of steam strainer rivets etc. The term small hole EDM drilling is used because conventional ram EDM can also be used for drilling. However, ram EDM hole drilling is much sluggish than machines specifically designed for EDM drilling. Small hole EDM drilling uses the same principles as ram EDM. A spark jumps across a gap and erodes the workpiece material. A servo drive maintains a gap between the electrode and the workpiece. If the electrode touches the workpiece, a short occurs. In such situations, the servo drive retracts the electrode. At that point the servo motor recollects its path and resumes the EDM process. But here the electrode is given rotation and through the electrode pressurized dielectric is passed

Drilling test has been performed on the EDM Machine of X, Y, Z travel 300 x 200 x 300mm, Electrode diameter 0.3 up to 3mm, the tool used here is brass material tool. The element zinc is added to copper to produce brass EDM wire, which is the most common EDM wire in use today. Brass wire for EDM are typically an alloy between 63/37 (American and European) to 65/35 (Asian), Cu/Zn ratio. Zinc has a lower melting/ vaporization point which make it a better electrode material than copper, so the more zinc in the surface of an EDM wire, the faster it will cut. However, manufacturing difficulties arise when the volume of zinc approaches 40% and its crystalline structure changes to a gamma phase, causing the wire to become very brittle and difficult to draw. However, there are two wires being produced with a 60/40 Cu/Zn content for faster cutting speeds.

Fig 2 workpiece setup

Fig 3 Brass tool

The mean surface roughness (Ra) is measured with a Mitutoyo Surf tester. Surface roughness often shortened to surface irregularities, is a component of surface texture. Roughness plays an important role in decisive how a real object will relate with its environment. Rough surface usually wear more quickly and have higher friction coefficients than smooth surface. Roughness is often a good seer of the performance of a mechanical component. On the other hand, roughness may promote adhesion.

Fig4 Surface Roughness Tester

Process Parameters and Their Levels

Table2 Parameter Levels

Parameter	Level 1	Level 2	Level 3
Current	14	17	20
Pulse on Time	8	9	10
Drill Diameter	2	2.5	3
Current in A			
Pulse on time in hertz.			
Drill diameter in mm			

L9 orthogonal array and the desired parameter values:

Table3 L9 Orthogonal Array

CURRENT	PULSE ON TIME	DRILL DIAMETER
14	8	2
14	9	2.5
14	10	3
17	8	2.5
17	9	3
17	10	2
20	8	3
20	9	2
20	10	2.5

Obtained Surface Roughness Values

Table 4 L9 Surface Roughness Values

CURRENT	PULSE ON TIME	DRILL DIAMETER	SURFACE ROUGHNESS
14	8	2	0.063
14	9	2.5	0.048
14	10	3	0.056
17	8	2.5	0.036
17	9	3	0.036
17	10	2	0.028
20	8	3	0.44
20	9	2	0.052
20	10	2.5	0.046

3. Results and Discussion

Each experiment is done three times and the mean values were calculated. After all experiments are done, decisions must be given depending on which parameter affects the performance of a process and a mathematical model is performed to predict output. According to the Taguchi method, the S/N ratio is the ratio of signal-to-noise where signal represents the desirable value (i.e. the mean for the output characteristic), and noise represents the undesirable value (i.e. the square deviation for the output characteristic).

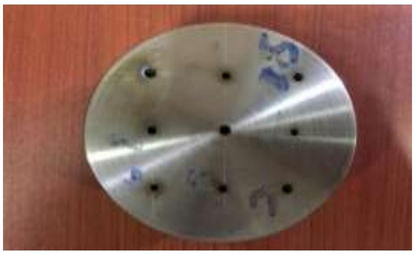

Fig5 Specimen after Drilling

Response and S/N Ratio for Surface Roughness

Table 5 Signal to Noise Ratio

Current	Pulse On Time	Drill Diameter	Surface Roughness	S/N ratio
14	8	2	0.063	24.0132
14	9	2.5	0.048	26.3752
14	10	3	0.056	25.0362
17	8	2.5	0.036	28.8739
17	9	3	0.036	28.8739
17	10	2	0.028	31.0568
20	8	3	0.44	7.1309
20	9	2	0.052	25.6799
20	10	2.5	0.046	26.7448

Response Table for Signal to Noise Ratio Smaller is better

Table6 Response Table for Smaller is better

Level	CURRENT	PULSE ON TIME	DRILL DIAMETER
1	25.14	20.01	26.92
2	29.60	26.98	27.33
3	19.85	27.61	20.35
Delta	9.75	7.61	6.98
Rank	1	2	3

Results

Analysis of Variance for SN ratios

Table7 Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
CURRENT	2	142.9	142.9	71.46	2.84	0.26	37
PULSE ON TIME	2	106.9	106.9	53.43	2.12	0.32	27
DRILL DIAMETER	2	92.11	92.11	46.06	1.83	0.353	23
Residual Error	2	50.32	50.32	25.16			13
Total	8	392.2					100

Optimal Factor Levels for Surface Roughness

Table8 Optimal Factor Level

S. No	Factors	Optimum value
1	Current	17
2	Pulse on Time	10
3	Drill Diameter	2

Residual plots for surface roughness

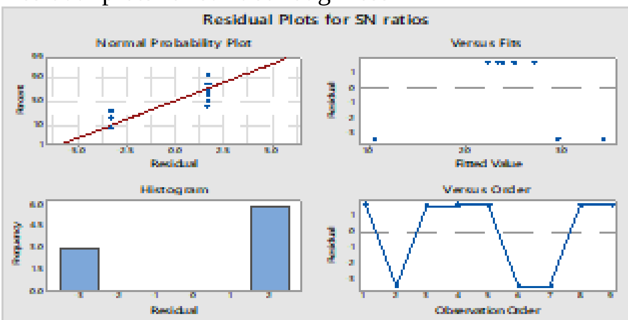

Figure 6 Residual plots

Main Effect Plot for S/N Ratios of Surface Roughness

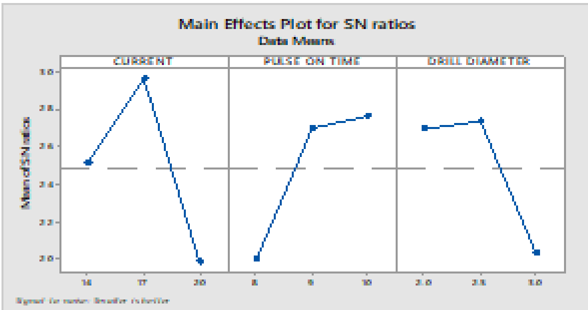

Figure7 Main Effect Plot for S/N Ratio

4. Discussions

From the above table of results, main factor that significantly influence the surface roughness is current. The contribution of this parameter is 37%. Analysis of variance for surface roughness is performed to study the influence of EDM drilling. The results for ANOVA performed for surface roughness are tabled above. A check for normality assumptions have been made by constructing the normal probability plots of the residuals. This is used to test the normal distribution of errors. If error distribution is normal this plot will resemble a straight line.

The assumptions are valid as per the plot obtained. From the above observations it has been noted that current and pulses on time are major factors that influence the surface roughness. Of this both parameters current is the major factor which is highly influencing the surface roughness in drilling the Titanium. After the parameters have been analysed it is noted that current of 17 A , pulse on time of 10 hz and with a drill diameter of 2.0 mm are the optimum values obtained for good surface finish.

5. Conclusions

The following conclusions can be drawn from the experiments done on the drilling of TITANIUM using DRILL-EDM with brass as electrode at constant voltage, varying current, varying pulse on time and diameter of the electrode. Demographically designed experiments based on Taguchi method are performed using L9 orthogonal array to analyze the effect of drilling parameters on surface roughness. From the analysis of results in the drilling process using conceptual analysis of variance (ANOVA) the following can be concluded from the present experiment. Current and Pulse on time are the key factors, which has greater influence on surface roughness. The current is the parameter which highly influences the surface roughness in the drilling of Titanium. After the parameters have been analyzed it is noted that current of 17 A, pulse on time of 10 hz and with a drill diameter of 2.0 mm are the optimum values obtained for good surface finish. Thus it is need to choose suitable combination of current and pulse on time so as to reduce the variations that can affect the quality of the holes that are drilled on Titanium material.

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