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ANALYSIS AND OPTIMIZATION OF Ti (Grade 5) ON µ- EDM BY TAGUCHI METHOD

Mohammad Arbaz[1], Vijayendra Kumar[2], Mohammad Faran Jamal[3], Sumit Verma[4]

[1,2]Research Scholar, Dept. Of Mechanical Engg., Suyash Institute Of Information Technology, Gorakhpur, U.P., India
[3]Research Scholar, Department Of Mechanical Engineerig, Integral University, Lucknow, U.P., India
[4]Associate Professor, Dept. Of Mechanical Engg., Suyash Institute Of Information Technology, Gorakhpur, U.P., India

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Abstract - *During the last decade there has been continuing demand of compact, integrated and small size product by a non-traditional process for accurate and cost effective measurement of material properties. These are needed for machining for tools and product design, the development of micro size components, the growing needs for micro feature generation. Micro – manufacturing processes have different material capabilities and machining performance specifications. Machining performance specification of concern include minimum feature size, tolerance, surface finish and MRR and application of advanced, which is very difficult to machine materials. They have made the µ- EDM an important t manufacturing process to meet these demands. µ- EDM technology has been widely used in production, aerospace, aircraft, medical and virtually all areas of conductive material machining. Ti (Grade 5) is ever produced in manufacturing industries. It's capable to withstand in very high temperature and the excellent resistance in mechanical and chemical debilitate. The Ti (Grade-5) Aluminium based super alloys are having high strength, thermal conflict with very hard material characteristics. It is also very good in corrosion resistance in many conditions of engineering applications. Due to very tough in nature and the machinability has been studied by many researchers on these materials and been carried out for last few years. This project presents the machining of the Ti materials using µ- EDM with in micro size. The objective of this project is to investigate the performance of µ-EDM machining on Ti Materials.*

***Key Words*: µ- EDM, Ti (Grade 5), MRR, Taguchi, Tolerance, EDM (electrical discharge machining)**

1. INTRODUCTION

µ-EDM or electrical discharge machining is achieved when a discharge take place between two points of the anode and cathode, the intense heat is generated near the zone melts and evaporates the materials in the sparking zone. For improving the effectiveness of the process, the work piece and the tool are submerged in a dielectric fluid (hydrocarbon or mineral oils). It has been observed that if both the electrodes are made of the same material, the electrode connected to positive terminal generally erodes at a faster rate. For this reason, the work piece is normally made the anode. A suitable gap, known as spark gap, is maintained between the tool and the work piece surfaces. Since the spark occurs at the spot where the tool and the work piece surfaces are the closest and since the spot changes after each spark (because of the material removal after each spark), the spark travels all over the surface. This results in uniform material removal all over the surface, and finally work piece conforms to the tool surface.

This machining method is commonly used for very hard metals that are impossible to machine with conventional machining methods.

Electrical discharge machining is basically electro-thermal non-traditional material removal process which is widely used to produce dies, punches, molds, finishing parts for aerospace and automotive industry, nozzles, machining of ceramics and composites and surgical components. The working process of EDM process (figure) is based on the thermoelectric energy. This energy is created between a work piece and an electrode submerged in a dielectric fluid with the passage of electric current.

1.1 µ-EDM PRINCIPLE

µ-EDM is carried out in a liquid medium, the machine's automatic feed adjustment device to the work piece and the tool electrode discharge gap between the right, when the tool is applied between the electrode and the work piece strong pulse voltage (up to the gap in the media breakdown voltage) when the lowest breakdown strength of dielectric insulation, as shown. The discharge area is small, the discharge time is very short, so a high concentration of energy, so that the instantaneous temperature of the discharge area of up to 10000-12000 °C, and tools for surface partial melting of the metal electrode surface, or even vaporized. Partial melting and vaporization of metal under the action of the explosive thrown into the working fluid, small particles of metal was cooling, and then quickly washed away by the working fluid work area, so that the surface to form a small pit. One discharge, the medium dielectric strength recovery waiting for the next discharge. This is repeated continuously so that the surface ablation, and copy the tool electrode on the work piece shape, so as to achieve the purpose of forming.

µ-EDM metal ablation is constantly discharging process. Although a pulse discharge time is very short, but it is electromagnetism, thermodynamics and fluid mechanics combined effects of such a process is quite complex

1.2 EDM machine tools working fluid and circulating filtration system

EDM, the role of the working fluid are the following:

a. The discharge end of the discharge gap after the resumption of the insulating state (deionization) to re-form under a pulse voltage spark discharge. Working solution for this requires a certain degree of insulation strength, the resistance rate between l03 ~ 106Ù • cm.

b. Make the product easier to pitting suspended from the discharge gap, excretion, so that serious pollution discharge gap, spark discharge point does not lead to the formation of dispersed harmful arcing.

c. Cooling and reducing the tool electrode surface discharge produced by the instantaneous local temperature, otherwise the surface will be generated due to local overheating coking, burns, and the formation of arc discharge.

d. The working fluid can be compressed spark discharge channel, increase channel compressed Gas, and the explosive expansion of the plasma in order to throw more melting and vaporization of the metal, increasing the amount of ablation. Currently using kerosene as the working fluid μ-EDM, because the new resistance of kerosene was 106Ù • cm, and the use of l05 ~ 104Ù • cm in between, and relatively stable, its viscosity, density, surface tension performance full compliance with the requirements of μ-EDM. But kerosene is easy to fire. So when the processing of crude Criteria should be used when the oil or oil mixed with the working fluid.

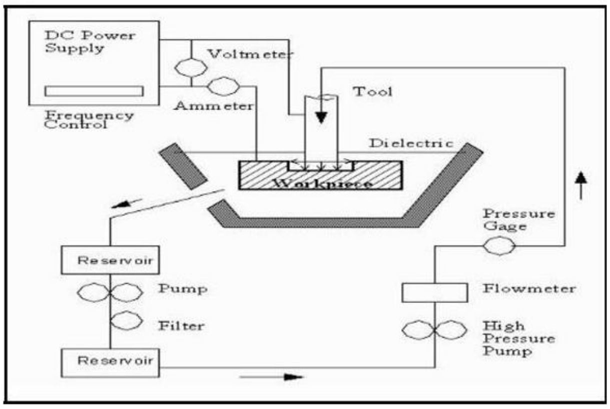

Figure 1.1: Micro-ELECTRICAL DISCHARGE MACHINING SETUP

1.3 ADVANTAGES OF μ-EDM

- Complex shapes that would otherwise be difficult to produce with conventional cutting tools.
- Extremely hard materials can be machined to very close tolerances.
- Very small pieces where conventional cutting tools may damage the part from excess cutting tool pressure.
- There is no mechanical contact between tool and the work piece. Therefore delicate sections and weak materials can also be machined without any distortion. •A good surface finish can be obtained.
- Very fine holes can be easily drilled by using μ-EDM machine.

1.4 DISADVANTAGES OF μ-EDM

- The slow rate of material removal.
- Reproducing sharp corners on the work piece is difficult due to electrode wear.
- Power consumption is very high.
- “Overcut” is formed.
- Excessive tool wear occur during machining.
- Electrically non-conductive materials can be machined only with specific setup of process.
- The additional time and cost used for creating electrodes for sinker μ-EDM.
- Potential fire hazards associated with use of combustible oil based dielectrics.

2. PROBLEM FORMULATION

On the basis of above study parameters peak current (Ip), pulse off time T(off) and pulse on time (Ton) are selected for this work to analyze the Material Removal Rate, Tool Wear Rate and Surface Roughness with Electrode diameter 1mm, 2mm and 3mm using machining parameters selected as Ip, Ton and T(off) using Taguchi L9 orthogonal array.

(a) To find influence on MRR to electrode diameter 1mm,2mm and 3mm with Ip, Ton and T (off).

(b) To find influence on TWR to electrode diameter 1mm,2mm and 3mm with Ip, Ton and T (off).

(c) To find influence on SR to electrode diameter 1mm,2mm and 3mm with Ip, Ton and T (off).

3. TAGUCHI METHOD

Taguchi has developed a methodology for the application of designed experiments, including a practitioner's handbook. This methodology has taken the design of experiments from the exclusive world of statistician and brought it more fully into the world of manufacturing. His contributions have also made the practitioner work simpler by advocating the use of fewer experimental designs, and providing a clear understanding of the variation nature and the economic consequences of quality engineering in the world of manufacturing. Taguchi introduces his approach, using experimental design for:

(a) Designing products/processes so as to be robust to environmental conditions.

(b) Designing and developing products/processes so as to be robust to component variation.

(c) Minimizing variation around a target value. This philosophy of Taguchi is broadly applicable.

He proposed that engineering optimization of a process or product should be carried out in a three step approach i.e. system design, parameter design and tolerance design. In system design the engineer applies scientific engineering knowledge to produce a basic functional prototype design. In the product design stage the selection of the materials, components, tentative product parameter values etc. are involved. Since system design is an initial step, functional design may be far from optimum in terms of quality and cost.

The objective of parameter design is to optimize the setting of process parameter value for improving performance characteristics and to identify the product parameter values under the optimal process parameter values. In addition, it is expected that the optimal process parameter values obtained from the parameter design are insensitive to the variation of environmental conditions and other noise factors. Therefore, the parameter design is the key step in Taguchi method of achieving high quality without increasing cost. Basically, classical parameter design developed by Fisher is complex and not easy to use especially, a large number of experiments have to be carried out when the number of process parameters increases. To solve this task, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. A loss function is then defined to calculate the deviation between the experimental values and desired values. Taguchi recommends the use of the loss function to measure the performance characteristic deviating from the desired value. The value of the loss function is further transformed into a signal-to-noise (S/N) ratio. Usually there are three categorize of performance characteristic in the analysis of the S/N ratio that is the lower-the-better, the higher-the-better, and the nominal- the –better. The S/N ratio for each level of process parameter is computer based on the S/N analysis. Regardless of the category of the performance characteristic, the larger S/N ratio corresponds to the better performance characteristic. Therefore, the optimal level of the process parameter is the level with the highest S/N and ANOVA analysis, the optimal combination of the process parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design. The Taguchi method is adopted to obtain optimal machining performance in the die sinking.

1. **Larger is better (maximum): S/NLB = -10 log ((1/n) Σ (1/y i ^{2}))**

2. **Smaller is better (minimum): S/NSB = -10 log ((1/n) Σ y i ^{2})**

Where, n is the number of observations or repetitions of a trial and y is the observed data. Notice that these S/N ratios are expressed on a decibel scale. We would use S/NT if the objective is to reduce variability around a specific target, S/NL if the system is optimized when the response is as large as possible and S/N"S if the system is optimized when the response is as small as possible. Factor level that optimizes the appropriate S/N ratio is optimal.

The use of parameter design of the Taguchi method to optimize a process with multiple performance characteristics includes the following steps:

(a) Identify the performance characteristics and select process parameters to be evaluated.

(b) Determine the number of levels for the process parameters and possible interactions between the process parameters.

(c) Select the appropriate orthogonal array and assignment of process parameters to the orthogonal array.

(d) Conduct the experiments based on the arrangement of the orthogonal array. Analyse the experimental result using S/N ratio and ANOVA.

4. EXPERIMENTAL SETUP

40ASEB EDM was used for machining the samples. The machine is as shown in the figure below. EDM is a „non-traditional" or „non-conventional" group of machining methods. Ideally, EDM can be as seen as a series of breakdown and restoration of the liquid dielectric in-between the electrodes. EDM uses spark erosion method to remove the material of the work piece.

Table 4.1 Technical Specifications of micro-EDM

S.No.	Specification	Value
1	Model	40ASEB
2	Dielectric Fluid	EDM Oil
3	Electrode	Copper (Cu)
4	Pulse-on-time	05-990
5	Pulse-of-time	01-90
6	Spark Time	01-09
7	Voltage	0-300V

WORK PIECE MATERIAL

The material used for this work is Ti Gr.5 specification of 20mm thickness and 38mm diameter.

Table 4.2 Composition of various element of Ti (Grade-5)

Ti	vanadium	Aluminum	Fe	O	C	H
88.86%	4.33%	6.01%	0.25 (Max)	0.2 (Max)	0.08 (Max)	0.015 (Max)

5. RESULT AND DISCUSSION

5.1 CALCULATION FOR MRR

$$MRR = \frac{(\text{Work piece weight loss (gm.)}) \times 1000}{\text{Density (gm. /cc)} \times \text{Machining Time (min)}}$$

Table 5.1 Calculation of TWR (tool wear rate)

Exp. No	Diameter	Current	T (on)	T (off)	TWR
1.	1	6	150	20	0.053
2.	1	7	300	40	0.041
3.	1	8	450	60	0.029
4.	2	6	300	60	0.084
5.	2	7	450	20	0.092
6.	2	8	150	40	0.056
7.	3	6	450	40	0.036
8.	3	7	150	60	0.037
9.	3	8	300	20	0.088

5.2 CALCULATION OF S/N RATIO FOR TWR

The S/N ratio, which condenses the multiple data points within a trial, depends on the type of characteristics being evaluated. For calculation of S/N ratio for TWR SMALLER IS BETTER condition is opted. This is considered as the defect and it should as low as possible.

The equation for the calculation of S/N ratio for TWR is:

$$S/N_{SB} = -10 \log ((1/n) \Sigma y i^2)$$

Table 5.3 Calculation of S/N ratio for TWR

S.NO	TWR	S/N Ratio
1.	0.053	25.5145
2.	0.041	37.0774
3.	0.029	30.7520
4.	0.084	21.5144
5.	0.092	20.7242
6.	0.056	25.0362
7.	0.036	28.8739
8.	0.037	28.6360
9.	0.088	21.1103
Average	0.057	17.3286

5.4 CALCULATION OF MEAN S/N RATIO FOR TWR

Mean S/N ratio is calculated by using following formula

N fi= (nf1+nf2+nf3)/3

Where NF is mean S/N ratio for factor f at the level value i of the selected factor.

Table 5.4-Response table for S/N ratio Smaller is better

Levels	Tool Dia	Ip	T (on)	T (off)
1	31.11	25.30	26.40	22.45
2	22.42	28.81	26.57	30.33
3	26.21	25.63	26.78	26.97
Delta	8.69	3.51	0.39	7.88
Rank	1	3	4	2

5.5 Confirmation Experiment

Table 5.5 Confirmation of TWR

S.No.	Optimum machining parameters				S/N ratio for TWR(dB)	
	Dia.	IP	Ton	Toff	Predicted	Experiment
1	2	8	300	20	17.3286	16.8560
					Error %	2.72

Table 5.6 Confirmation of MRR

S.No.	Optimum machining parameters				S/N ratio for MRR(dB)	
	Dia.	Ip	Ton	T(off)	Predicted	Experiment
1	2	8	300	20	-11.3450	-11.0017
					Error%	3.12

6. CONCLUSION

It is observed that the taguchi‟s parameter is a simple, systematic, reliable and more efficient tool for optimization of the machining parameters. The effect of various parameters such as tool Dia, peak current, pulse on time, and pulse off time has been studied though machining of Ti (Grade 5). It was notice that the tool diameter and pulse off time have influenced more than the other parameter considered in this study. The confirmation experiment has been conducted. Result show that the error associated with SR is only 2.63%, MRR 3.12% and TWR 2.72%. The selection of optimum value is essential for the process automation and implementation a computer integrated manufacturing system.

SEM technique was used to characterize the surface and study the material phenomenon. SEM was used for studying the material migration phenomenon. Surface characterization revealed the pressure of micro dimensional craters, debris, solidified material, and micro-voids.

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