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# EFFECT OF EDM PROCESS PARAMETERS ON TOOL WEAR USING EN 31 TOOL STEEL

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## ABSTRACT

New developments in the field of material science have led to new engineering metallic materials, composite materials and high-tech ceramics, having good mechanical properties and thermal characteristics also sufficient electrical conductivity so that they can readily be machined by spark erosion. At the present time, Electrical discharge machine (EDM) is a widespread technique used in industry for high-precision machining of all types of conductive materials such as: metals, metallic alloys, graphite or even some ceramic materials. In this paper experimentation on EN-31 material with Copper as Electrode material using EDM is proposed. Various Process parameters namely Discharge Current (DC), Pulse on Time, Pulse off Time etc. have been considered. The process performance is measured in terms of Response variable like Tool Wear. Number of experiments conducted is based on Taguchi method using L9 Orthogonal Array with three level and three factors. The aim of the present study is to investigate the variation of Tool wear with the varying machining parameters (Ton, Toff and discharge current) in die sinking EDM. Variation of responses with respect to each input machining parameter is presented and analyzed. This study shows that in case of tool wear, discharge current (DC) is the effective parameter after that the Pulse on Time and the Pulse off Time are having less effect on tool wear.

**KEYWORDS:** EDM, Tool Wear, D.C. $T_{ON}$, $T_{OFF}$, TAGUCHI METHOD

## INTRODUCTION

The electro discharge machining (EDM) process involves a controlled erosion of electrically conductive materials by the irritation of rapid and repetitive spark discharged between the cathode (electrode tool) and anode (work piece) separated by small gap of about 0.01 to 0.50 mm known as spark gap. The spark gap is either flooded or immersed under dynamic fluid. The spark discharge is produced by the controlled pulsing of direct current between the work piece and tool. The dielectric fluid is ionized by spark thus enabling spark discharge to pass between the tool and work piece. EDM process in corporate a unique feature absence of any cutting force between the work piece and tool. Electric discharge machining (EDM), sometimes colloquially also referred to as spark machining, spark eroding, burning, die sinking or wire erosion is a manufacturing process . When the distance between the two electrodes is reduced, the intensity of the electric field in the volume between the electrodes becomes greater than the strength of the dielectric which breaks, allowing current to flow between the two electrodes, as a result, material is removed from both the electrodes (cathode and anode)

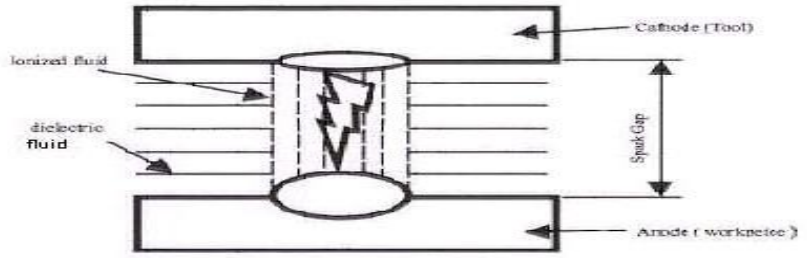


Fig 1 Principal of Working of ED Machine

Once the current flow stops new liquid dielectric is usually conveyed into the inter-electrode volume enabling the solid particles (debris) to be carried away and the insulating proprieties of the dielectric to be restored. Adding new liquid dielectric in the inter-electrode volume is commonly referred to as flushing The parts produced by EDM process generally have intricate shapes, made up of hardened materials and electrically conductive materials .In 1995 the Swiss company CHARMILLE introduced for the first time world wide at European machine tool exhibition in Milan Italy

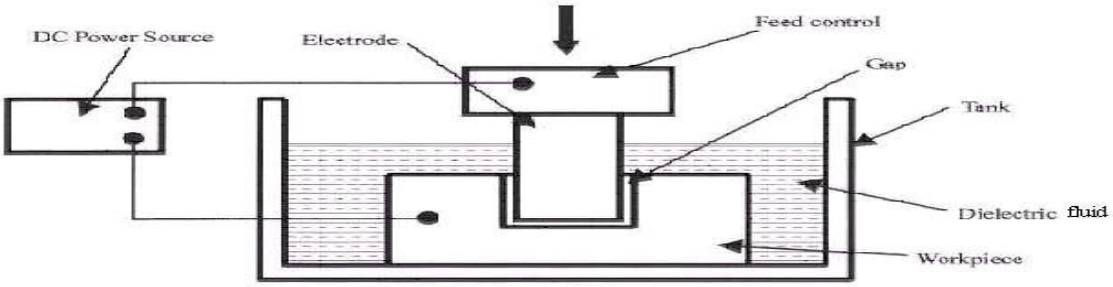


Fig 2 Electric Discharge Machine Description

## LITERATURE REVIEW

**Avdesh Chandra Dixit, Amit Kumar, Ravindra Kumar Singh, Rahul Bajpai (1)** studied the influence of EDM parameters on MRR, EWR while machining of AISI D3 Material. The parameters considered are pulse-on time (Ton), pulse off time (Toff) peak current (Ip) and fluid pressure. The experiments were performed on the die-sinking EDM machine fitted with a copper electrode. The experiments planned, conducted and analyzed using Taguchi method. It is found that the MRR is mainly influenced by (Ip); where as other factors have very less effect on material removal rate. Electrode wear rate is mainly influenced by peak current (Ip) and pulse on time (Ton), fluid pressure has no effect on electrode wear rate**.**

**N. Mathan Kumar, S. Senthil Kumaran, L.A. Kumaraswamidhas (2)** investigated on the Aluminum 2618 composite work piece using a copper electrode in an EDM machining. The study find out Current(I), Pulse on time(TON), Pulse off time (TOFF) on Metal Removal Rate (MRR),Tool Wear Rate(TWR) on the machining of hybrid Al2618 metal matrix composites. Taghuchi's design of experiment was used to analyse the machining characteristics of hybrid composites. To effect the parameters like current (I), Pulse on time (TON), Pulse off time (TOFF) has been chosen as the input parameters of this work. Machining results go to show that Al2618 composites have improved mechanical properties and as a result of Material Removal Rate (MRR) and Tool Wear Rate (TWR) are reduced. Hence ANOVA (Analysis of Variance) and signal to Noise ratio are used to determine the influence of input parameters on the Material Removal Rate and Tool Wear Rate (TWR).

**Nibu Mathew, Dinesh Kumar, Naveen Beri, Anil Kumar (3)** performed experimentation to compare the usefulness of electrode made through Powder Metallurgy (PM) in comparison with conventional copper electrode during electric discharge machining. Experimental results are presented on electric discharge machining of H11 steel

in standard EDM oil with copper tungsten (75% Cu and 25%W) tool electrode made through powder metallurgy technique and Copper electrode (99%Cu). An L18 (21 X 33) orthogonal array of Taguchi Methodology was used to identify the effect of process input parameters (viz. electrode type, peak current, voltage and duty cycle) on the output factor (viz. Tool wear rate). It was found that copper tungsten (CuW) made through powder metallurgy gives better TWR as compared to conventional electrode (Cu) and the best parametric setting for minimum TWR is with CuW powder metallurgy tool electrode, 4 ampere current, 40 volts gap voltage, 0.72 duty cycle, i.e., A2B1C1D1.

**Subhakanta Nayak, Puspa Ranjan Swain (4)** study the influence of operating parameters of EDM of tungsten carbide on the machining characteristics. The effectiveness of EDM process with tungsten carbide is evaluated in terms of material removal rate, the relative wear ratio and the surface finish quality of the workpiece produced. It is observed that copper tungsten is most suitable for use as the tool electrode in EDM of tungsten carbide.

**Teepu Sultan, Anish Kumar, and Rahul Dev Gupta (5)** worked on Material Removal Rate, Electrode Wear Rate, and Surface Roughness Evaluation in Die Sinking EDM with Hollow Tool through Response Surface Methodology. The optimization was performed in two steps using one factor at a time for preliminary evaluation and a Box-Behnken design involving three variables with three levels for determination of the critical experimental conditions. Pulse on time, pulse off time, and peak current were changed during the tests, while a copper electrode having tubular cross section was employed to machine through holes on EN 353 steel alloy workpiece. The results of analysis of variance indicated that the proposed mathematical models obtained can adequately describe the performances within the limits of factors being studied. The experimental and predicted values were in a good agreement.

**Arvind Kumar Tiwari, Jasvir singh (6)** performed experimentation for Optimization of EDM Process of (Cu-W) EDM Electrodes on Different Progression. They studied the optimal cutting condition of EDM process of different work piece materials using different compositions of Cu-W tool Electrodes.

**Shivendra Tiwari (7)** worked on Optimization of Electrical Discharge Machining (EDM) with Respect to Tool Wear Rate. To make EDM economic and effective they studied and experimented by controlling the process parameters like peak current, gap voltage, pulse on time, polarity, current density, dielectric medium, shape and size of electrode etc .In this Research work various parameters which affect the tool wear rate is identified. Copper is used as tool material.

**Ali Ozgedik, Can Cogun (8**) studied on an experimental investigation of tool wear in electric discharge machining. In this study, the variations of geometrical tool wear characteristics – namely, edge and front wear and machining performance outputs – namely, workpiece removal rate, tool wear rate, relative wear and workpiece surface roughness – were investigated with varying machining parameters. Experiments were conducted using steel workpieces and round copper tools with a kerosene dielectric under different dielectric flushing conditions (injection, suction and static), discharge currents and pulse durations. The experiments have shown that machining parameters and dielectric flushing conditions had a large effect on geometric tool wear characteristics and machining performance outputs.

**Laurenţiu, Schulze, Dodun, Coteaţa et al. (9)** performed experimentation on Electrode Tool Wear at electrical discharge machining. Some theoretical considerations are used to highlight the electrode wear depending on the energy of the electrical discharges and the mass of the electrode aspects. A set of experimental tests was designed and developed in order to highlight the influence exerted by the nature of the workpiece material and by the size of the cross section of the electrode, respectively, on the electrode wear. Empirical mathematical models corresponding to the evolution of the electrode wear were established.

**M. S. Azad & A. B. Puri (10)** worked on simultaneous optimisation of multiple performance Characteristics in micro-EDM drilling of titanium alloy. They made attempt for simultaneous optimization of the process performances like metal removal rate, tool wear rate and overcut based on Taguchi methodology. Thus, the optimal micro-EDM process parameter settings have been found out for a set of desired performances. The process parameters considered in the study were pulse-on time, frequency, voltage and current while tungsten carbide electrode was used as a tool. Verification experiments have been carried out and the results have been provided to illustrate the effectiveness of this approach.

**E. Aliakbari & H. Baseri (11**) performed experiment to optimize machining parameters in rotary EDM process by using the Taguchi method. In this study, the optimal setting of the process parameters on rotary EDM was determined. A total of three variables of peak current, pulse on time, and rotational speed of the tool with three types of electrode were considered as machining parameters. Then some experiments have been performed by using Taguchi's method to evaluate the effects of input parameters on material removal rate, electrode wear rate, surface roughness, and overcut. Moreover, the optimal setting of the parameters was determined through experiments

planned, conducted, and analyzed using the Taguchi method. Results indicate that the model has an acceptable performance to optimize the rotary EDM process.

**K. M. Patel & Pulak M. Pandey & P. Venkateswara Rao (12)** experimented on process parameters for multi-performance characteristics in EDM of Al2O3 ceramic composite. Experiments were conducted using discharge current, pulse-on time, duty cycle and gap voltage as typical process parameters. The grey relational analysis was adopted to obtain grey relational grade for EDM process with multiple characteristics namely material removal rate and surface roughness. Analysis of variance was used to study the significance of process variables on grey relational grade which showed discharge current and duty cycle to be most significant parameters. Other than discharge current and duty cycle, pulse-on time and gap voltage have also been found to be significant. To validate the study, confirmation experiment has been carried out at optimum set of parameters and predicted results have been found to be in good agreement with experimental findings.

**Jong Hyuk Jung and Won Tae Kwon (13**) worked on optimization of EDM process for multiple performance characteristics using Taguchi method and Grey relational analysis. They attempted to find the optimal machining conditions under which the micro-hole can be formed to a minimum diameter and a maximum aspect ratio. The Taguchi method was used to determine the relations between machining parameters and process characteristics. It was found that, electrode wear and the entrance and exit clearances had a significant effect on the diameter of the micro-hole when the diameter of the electrode was identical. Grey relational analysis was used to determine the optimal machining parameters, among which the input voltage and the capacitance were found to be the most significant. The obtained optimal machining conditions were an input voltage of 60V, a capacitance of 680pF, a resistance of 500Ω, the feed rate of 1.5μm/s and a spindle speed of 1500rpm. Under these conditions, a micro-hole of 40μmaverage diameter and 10 aspect ratio could be machined.

**S. Singh (14**) experimented for Optimization of machining characteristics in electric discharge machining of 6061Al/Al2O3p/20P composites by grey relational analysis. This investigation applied the designs of experiments and grey relational analysis (GRA) approach to optimise parameters for electrical discharge machining process of 6061Al/Al2O3p/20P aluminum metal matrix composites. L18 (2^1×3^5) orthogonal array to determine an optimal setting. The process parameters included one noise factor, aspect ratio having two levels and five control factors, viz. pulse current, pulse ON time, duty cycle, gap voltage and tool electrode lift time with three levels each. The material removal rate, tool wear rate and surface roughness were selected as the evaluation criteria.

## PROPOSED METHODOLOGY

In this process experiments are to be carried out on Electrical Discharge Machine. The tool electrode is a cylinder of Copper of 10 mm diameter and 30 mm height. EN 31 was selected as work piece with size- 100 x 100 x 10 mm (shape- Rectangle). Based on Literature survey parameters chosen as input parameters are input current, pulse On time and pulse Off time with the Tool Wear as output parameter. Spark gap, Dielectric fluid and voltage are the constant parameters. Machining Parameters and their Levels are shown below in Table: 1

Table 1: Levels of machining parameters

| Machining Parameter | Symbol | Unit | Levels | | |
|---|---|---|---|---|---|
| | | | Level 1 | Level 2 | Level 3 |
| Discharge Current (DC) | DC | A | 5 | 10 | 12 |
| Pulse On Time (Ton) | Ton | μs | 25 | 75 | 150 |
| Pulse Off Time (Toff) | Toff | μs | 12 | 25 | 37 |

**Taguchi Orthogonal Array Design for EDM.**

Table 2:Taguchi orthogonal array

| Experiment | DC (Amp) | Ton(µs) | Toff(µs) |
|---|---|---|---|
| 1 | 5 | 25 | 12 |
| 2 | 5 | 75 | 25 |
| 3 | 5 | 150 | 37 |
| 4 | 10 | 25 | 25 |
| 5 | 10 | 75 | 37 |
| 6 | 10 | 150 | 12 |
| 7 | 12 | 25 | 37 |
| 8 | 12 | 75 | 12 |
| 9 | 12 | 150 | 25 |

## EXPERIMENTATION

The experimentation is performed by operating on Electrical Discharge Machine classified as Die- Sinker Type, CHMER 50 NZ whose polarization on Electrode be located as Positive and that of Work piece be located as Negative. Dielectric recycled is EDM Oil. The machine contains following measures-

1. Power Supply unit and CNC function
2. Leak proof tank along with tool fixing chuck.
3. Tool holding device
4. Servo control unit for vertical movement of the tool.

## CONDUCT OF EXPERIMENT

Copper as tool material having 10 mm solid diameter and the die sinker EDM machine is used. EDM oil was used as dielectric fluid (Specific Gravity = 0.763, Freezing Point 94ºC) to perform experiment. Manual Side flushing was used to flush away the eroded material from the sparking zone. For a three level and three factors, total 9 trials are completed on Die sinking EDM. The results of these trials are tabulated as below in **Table: 3**

## RESULTS

Table 3: Results of trials

| Test Runs | Parameters | | | |
|---|---|---|---|---|
| | DC (Amp) (A) | Ton µs | Toff µs | Twear (mm) |
| 1 | 5 | 25 | 12 | 0.13 |
| 2 | **5** | **75** | **25** | **0.1** |
| 3 | 5 | 150 | 37 | 0.6 |
| 4 | 10 | 25 | 25 | 1.05 |
| 5 | 10 | 75 | 37 | 0.96 |
| 6 | 10 | 150 | 12 | 1.9 |
| 7 | 12 | 25 | 37 | 1.35 |
| 8 | 12 | 75 | 12 | 1.84 |
| 9 | 12 | 150 | 25 | 2.35 |

## CONCLUSION

The Experiment was performed with Copper by taking the entire parameters constant except of current, pulse on time and pulse off time in die sinking EDM. The individual effect of current, pulse on time and pulse off time is analyzed and given below

**Effect of Current on Tool wears**

Observation from the present experiment is that the increase in current increases the Tool Wear. Minimum Tool Wear is produced at 5A and maximum Tool wear is produced at 12A.

**Effect of Pulse On Time on Tool wear**

The pulse on time is another factor that shows the variation in Tool wear. Minimum tool wear is produced at 75µs.

**Effect of Pulse Off Time on Tool wear**

The pulse off time is another factor that shows the variation in Tool wear. Minimum tool wear is produced at 25 µs.

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