CONTROLLING THE TOOL WEAR FOR THE ELECTRODE OF EDM WHILE OFFERING STATISTICAL TECHNIQUES AND OPTIMIZATION TECHNIQUES FOR PROBLEM SOLVING

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ABSTRACT

The accuracy of the dimension or the sharpness of a feature for EDM is highly influenced by the rate and extent of 'tool wear' i.e. the wear or erosion occurring over the electrode during material removal. The tool wear, in turn is influenced by machining parameters and the corresponding level set for the operation. Few of the parameters shall be offered variation within the operating rage to study its effect over the response i.e. the tool wear. Analytical tools shall be used to determine the optimal level for the given parameter in an effort to control or reduce the tool wear. Experimentation to be conducted over the machine setup shall offer validation for the solution proposed towards conclusion of this research. Minitab is considered for use to offer analytical treatment to the data secured during the research work. Tool wear shall be measured either by 'weight loss' of the electrode or with the use of 'Profile projector' to capture the extent of wear.

KEYWORDS: *Minitab, EDM, Optimization, Tool wear, Taguchi, Electrode*

I. INTRODUCTION

To overcome disadvantages of conventional machining processes, the EDM process is harnessed by the Die-Mold industry. Electrical discharge machining is a machining method primarily used for hard metals or those that would be very difficult to machine with traditional techniques. EDM typically works with materials that are electrically conductive, although methods for machining insulating ceramics with EDM have also under development. EDM can cut intricate contours or cavities in pre-hardened steel without the need for heat treatment to soften and re-harden them which normally introduces distortion. This method can be used with any other metal or metal alloy such as titanium, hastelloy, kovar, and inconel. Also, applications of this process to shape polycrystalline diamond tools have been reported.

EDM finds its wide applicability in manufacturing of plastic moulds, forging dies, press tools, die castings, automotive, aerospace and surgical components. In EDM, the spark generated using a high current source effects erosion of the material. No direct contact is made by EDM between the electrode and the work piece. This process offers the advantage of being devoid of any residual stresses, chatter and vibration problems during machining.

Parts made using EDM process are shown in Figure 1.

Figure 1: Parts manufactured using EDM

Characteristics of EDM

(a) The process can be used to machine any work material if it is electrically conductive
(b) Material removal depends on mainly thermal properties of the work material rather than its strength, hardness etc
(c) In EDM there is a physical tool and geometry of the tool is the positive impression of the hole or geometric feature machined
(d) The tool has to be electrically conductive as well. The tool wear once again depends on the thermal properties of the tool material
(e) Though the local temperature rise is rather high, still due to very small pulse on time, there is not enough time for the heat to diffuse and thus almost no increase in bulk temperature takes place. Thus the heat affected zone is limited to 2 – 4 μm of the spark crater
(f) However rapid heating and cooling and local high temperature leads to surface hardening which may be desirable in some applications
(g) Though there is a possibility of taper cut and overcut in EDM, they can be controlled and compensated.

Problem definition

EDM as a non-conventional machining process is useful in more than one way, although the process itself offers serious limitations for the Industry, while the convenience of machining inaccessible areas with high precision is well known this process needs to overcome inherent inefficiencies that limit its usage. The accuracy of the operation can be relied upon so far as the electrode, its shape and size, remains intact. Practically, as the operation progresses, the electrode (tool) begins to wear out due to the erosive nature of the process. Extensive tool wear diminishes the sharpness of the features cut during the operation. Replacement of the tool adds to the cost of spares and the down time of the process leading to increased over heads. The setting tool during the change-over (Replacement) also is a tricky task which if not done correctly shall lead the rejection of the machined part. All these problems at the tool room can be directly attributed to the tendency of tool wear. Any efforts in reducing the extent of tool wear shall improve the productivity which enhancing the sharpness and accuracy of the operation. Factors need to be identified that leads to increased rate of tool wear. Such factors should be controlled for realizing a balance between the rate of production as well as the precision delivered by the process (EDM). Since copper electrodes are used for majority of the cases in the industry, a study needs to be conducted over electrodes made of electrolytic copper that would help optimize the process for this output parameter (rate of tool wear)

II. 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 aluminium 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

III. PROJECT OVERVIEW

3.1 scope of work/ objectives

1. Study the application of workpiece, accuracy required in process, material used for workpiece and tool through Literature Review.
2. Identify the process parameters that significantly affect the response of interest i.e. Tool wear
3. Identify the material for the workpiece and electrode, dielectric fluid, pulse ON/OFF time, current rating
4. Select the levels for the parameters undertaken for this study while referring to historical data and Literature Review
5. Perform DOE using Taguchi method or a suitable method for Analysis
6. Determine optimal level for the input parameters vis-à-vis the Tool wear
7. Conduct experiment for validation

3.2 proposed work

- For this case study we are using two different methodologies such as Statistical Method and Experimental Method.
- In statistical method, basic problem solving techniques are used. In this work, DOE (Design of Experiments) methodology was used for optimizing process parameters of EDM process.
- DOE includes following techniques
  - Historical data analysis
  - Taguchi analysis
  - Regression analysis
  - ANOVA analysis

3.2.1. Procurement of raw material

Procurement of raw material as per design of experiment (samples of EN31 workpiece material, Electrode material copper and dielectric fluid kerosene)

3.2.2. Experimental Set up and Procedure

In this process, the metal is removed from the work piece due to erosion by rapidly recurring spark discharge, taking place between the tool and work piece. Figure 1 shows the experimental set up of Electrical Discharge Machine. A thin gap is maintained between the tool and the work piece by a servo system. Both the tool and the work piece are submerged in a dielectric fluid. Kerosene/EDM oil or deionised water is a very common type of liquid dielectric although gaseous dielectrics are also used in certain cases. The tool is cathode and the work piece is anode. When the voltage across the gap becomes sufficiently high, it discharges through the gap in the form of the spark at the interval of about 10 microseconds.

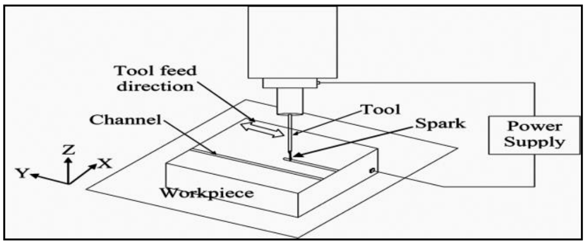


Figure.1 EDM Process

Figure.2 Typical Test setup for EDM Process & specifications

The positive ions and the electrons are accelerated to produce a discharge channel that becomes conductive. The spark jumps causing collision between ions and electrons, when a sudden drop of the electric resistance of the previous channel allows that current, density reaches very high values producing an increase of ionisation and the creation of a powerful magnetic field. The moment spark yields pressure developed between the work and the tool because of which a very high temperature is reached and at such high pressure and temperature some metal gets melted and eroded. Such localised extreme rise in temperature leads to material removal, which occurs due to instant vaporisation of the material.

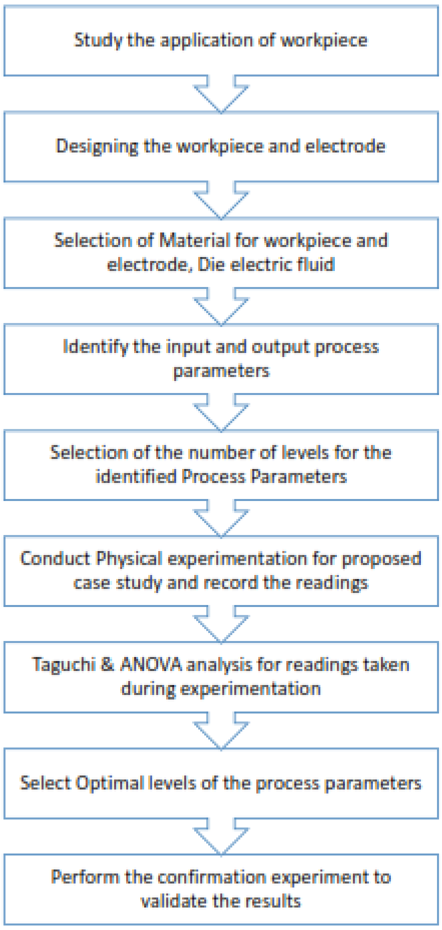
3.3.3 Experimentation

The effect of various input parameters were studied through the experimentation. All the factors were varied at 3 levels thus the L9 orthogonal array is used for experimentation.

3.3.4 Analysis and results

For the analytical purpose, Minitab 14 software shall be used. In this dissertation work, we shall use the tools such as Taguchi Method/ANOVA/ Grey Analysis/ Genetic algorithm/ Regression Equation. For the result analysis ANOVA is preferred .Results achieved are compared with results of experimental EDM.

IV. FLOW CHART OF METHODOLOGY



V. LAYOUT AND DESIGN OF THE SETUP

Figure 2 shows the Pictorial View of Electrical Discharge Machine. EDM consists of an electrode and the work piece. Two metal parts submerged in an insulating liquid are connected to a source of current, which is switched on and off automatically depending on the parameters set on the controller. When the current is switched on, an electric tension is created between the two metal parts. If the two parts are brought together within a fraction of a mm, the electric sparks are discharged and jump across. The electric tension strikes the metal and the metal gets heated up and then melts. The electrode is lowered automatically by the machine so that the process can continue uninterrupted. Several hundred thousand sparks occur per second, with the actual duty cycle carefully controlled by the setup parameters

VI. CONCLUSION

From the Literature Review it can be concluded that the Taguchi Method is widely used technique for the optimization of machining parameters

-Literature review also reveals that machining by EDM is generally assessed on the basis of MRR (Material removal rate), TWR (Tool wear rate) & SR (Surface roughness)

-The performance is affected by the discharge current, pulse ON/OFF time, spark gap, etc

6.1 Expected Outcome

Using the different statistical tools, the outcome would be giving the best parameters combination for the minimum tool wear for EDM on EN31 with Cu electrode.

6.2. Facilities available

6.2.1. A.G.P.I.T. Solapur

- Handbooks, reference books and e-journals are available at central digital library
- Computer facility, internet facility and necessary softwares are available in the laboratory

6.2.2. Ethika Engineering Solutions (I) Pvt. Ltd., Pune

Following facilities are provided with Ethika Engineering Solutions (I) Pvt. Ltd., Pune for Technical Sponsorship for Mechanical assignment.

- Facility provided to observe and perform experiment set up for EDM.
- To observe different process parameters.
- Taking readings for tool wear
- Library facility for books/ journal.
- Manufacturing and testing facilities in workshop or test lab.

6.3 Validation:

Validating the tool wear of the workpiece by comparing results obtained from experimentation with results ANOVA analysis. The experimentation work for finding tool wear will not be done; as it will required more time and also it is costlier. The tool wear of workpiece is considered as a ‘response' parameter for validation.

VII. FUTURE SCOPE

- Journal papers from varied sources could be explored to identify other `Responses’ of importance for the EDM process

434Z+50EZ Sinker EDM	**Unit**	**Dimensions**
Table size (WxD)	mm/inch	650×400/25.5×15.7
Table travel (XxY)	mm/inch	400×300/15.7×11.8
U,V axis travel (OB)	mm	±5
Work tank size (WxDxH)	mm/inch	1050×600×300/41.3×23.6×11.8
Ram travel (Z1)	mm/inch	350/13.8
Distance form RAM platen work table	mm/inch	200~550/7.8~21.6
Max. electrode weight (without OB)	kg/lb	100/220
Max. electrode weight (with OB)	kg/lb	15/33
Max. workpiece weight	kg/lb	750/1650
Outside dimensions (WxDxH)	mm/inch	1400×1340×2190/55×52.7×86.2
Weight	kg/lb	1400/3080
For Dielectric	-	D434

- Influence of di-electric fluid and/or workpiece material could be studied using alternatives

- Electrode materials with hot-hardness could be explored that shall offer good electrical properties while restricting the tool wear

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