THE EFFECTS OF MACHINING PARAMETERS ON SURFACE ROUGHNESS OF MATERIAL EN-31 IN EDM USING COPPER ELECTRODE

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ABSTRACT

The paper represent the work done for making mathematical models for analysis of the effects of machining parameters on the performance characteristics in EDM process of Alloy steel (EN-31). The mathematical models are developed using the response surface methodology (RSM) to explain the influences of machining parameters on the performance characteristics in the EDM process.

KEYWORDS: EDM, EN-31, Electrode, Surface Roughness, Machining.

INTRODUCTION

In the EDM process, the surface layer of a work piece can be rapidly melted and removed by an arc of 8,000-12,000^{0}C at each charge point The correct selection of manufacturing conditions is one of the most important aspects to take into consideration in the majority of manufacturing processes and, particularly, in processes related to Electrical Discharge Machining (EDM). Over the past few years, EDM has been widely applied in the modern metal industry for producing intricate and complex shapes. It is a capable of machining geometrically complex or hard material components, that are precise and difficult-to-machine such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. being widely used in die and mold making industries, aerospace, aeronautics and nuclear industries [1].
EDM Process characteristics are Metal Removal Rate, Accuracy, Surface finish and heat affected zone. EDM is most widely used machining process among the nontraditional machining methods. EDM is required for manufacturing and reconditioning of press tool and forging dies and mould for injection molding.

In these processes, electricity is used as direct means to cause machining action, moreover; the metal removal takes place in sizes of the order of microns. Here no chips are form like in conventional processes; material is removed by melting or vaporizing small area at the surface of the work piece. These are widely used for very hard materials. Also these are useful for producing complex and irregular shapes and cavities, which are difficult to produce by conventional processes [1].

The benefits of EDM include:

- EDM is a non-contact process that generates no cutting forces, permitting the
- production of small and fragile pieces
- Burr-free edges are produced
- intricate details and superior finishes are possible
- EDM machines with built-in process knowledge allow the production of
- intricate parts with minimum operator intervention

The limitations of EDM include:

- low metal removal rates compared to chip machining
- lead time is needed to produce specific, consumable electrode shapes

LITERATURE REVIEW

Abbas et al, Solomon et al and Bahari et al [2006] have been studied the recent trends in the field of Electrical discharge machining (EDM) which is one of the earliest non-traditional machining processes.

Dhar and Purohit [1] evaluates the effect of current (c), pulse-on time (p) and air gap voltage(v) On MRR, TWR, ROC of EDM with **Al–4Cu–6Si alloy–10 wt. % SiCP composites**.

Karthikeyan et .al [2] has presented the mathematical modeling of EDM with **aluminium-silicon carbide particulate composites**. Mathematical equation is $Y=f(V, I, T)$. And the effect of MRR, TWR, SR with Process parameters taken in to consideration were the current (I), the pulse duration (T) and the percent volume fraction of Sic (25 μ size). A three level full factorial design was choosing. Finally the significant of the models were checked using the ANOVA.

Kuang-Yuan Kung et al (2007) [3] In this article, a material removal rate (MRR) and electrode wear ratio (EWR) study on the powder mixed electrical discharge machining (PMEDM) of cobalt-bonded tungsten carbide (WC-Co) has been carried out.

N.Arunkumar , H.Shareef Abdur Rawoof and R.Vivek (2012) [4] This paper presents the results of experimental work carried out in electrical discharge machining (EDM) of EN31 (air hardened steel) using three different tool materials namely copper, aluminium and EN24, and also the problems involved in using graphite and brass as tool material.

Shankar Singh, S. maheswari, P. C. Pandey (2004)[5] worked on “Some investigations into the electric discharge machining of hardened tool steel using different electrode materials” Modern EDM is capable of machining geometrically complex or hard materials components that are precise and difficult to machine such as heat treated tool steels, composites, super alloys, ceramics, etc.

Chiang [15] proposed mathematical models for the modeling and analysis of the effects of machining parameters on the performance characteristics in the EDM process of Al2O3+TiC mixed ceramic which are developed using the response surface methodology (RSM) to explain the influences of four machining parameters (the discharge current, pulse on time, duty factor and open discharge voltage) on the performance characteristics of the material removal rate (MRR), electrode wear ratio (EWR), and surface roughness (SR).

Kansal .H.K et al.,(2005) [6] studied the Parametric optimization of powder mixed electrical discharge machining by response surface methodology and observed that there is discernible improvement in surface roughness of the work surfaces and MRR after suspending the silicon powder into the dielectric fluid of EDM.

Pecas and Henriques [2003] have found that Electrical discharge machining (EDM) is a technological process with a large industrial implementation.

Yan Cherng Lin, Biing Hwa Yan, Yong Song Chang [7] Worked on “Machining characteristics of titanium alloy (Ti-6Al-4V) using a combination process of EDM”.

Ashok Kumar et al. [19] machined the En-19 tool steel by using U-shaped copper electrode perform on electrical discharge machine. Where Diameter of U-shaped electrode, Current and Pulse on time are taken as process input parameters and material removal rate, tool wear rate, Overcut on surface of work piece are taken as output parameters.

Kuldeep Ojha et al.[18] studied the parametric optimization for material removal rate (MRR) and tool wear rate (TWR) on the powder mixed electrical discharge machining (PMEDM) of EN-8 steel has been carried out.

M.K. Pradhan (2008) [8] Response surface methodology was used to investigate the relationships and parametric interactions between the three controllable variables on the material removal rate (MRR).

M.R. Shabgard, R.M.Shotorbani (2009) [9] FW4 is a newly developed hot die material widely used in Forging Dies manufacturing. The right selection of the machining conditions is one of the most important aspects to take into consideration in the Electrical Discharge Machining (EDM) of FW4.

OTHER IMPORTANT RESEARCHERS TO BE MENTIONED

M. M. Rahman, Md. Ashikur Rahman Khan, K. Kadirgama M. M. Noor and Rosli A. Bakar (2010) [10]

Biing Hwa Yan Che Chung Wang, worked on “the machining characteristics of Al203/6061 Al composite using rotary electro-discharge machining with a tube electrode”

Han-Ming Chow, Biing-Hwa Yan, fuang- Yuan Huang, Jung-Cherng Hung, worked on “Study of added powder in kerosene for the micro-slit machining of titanium alloy using electro-discharge machining”

From the various literatures that has been reviewed it is understood that much work has not been done with the machining of EN-31, which happens to be a widely used material in the manufacturing of ball and roller bearings, spinning tools, beading rolls, punches and dies. EN-31 is a high carbon alloy steel which achieves a high degree of hardness with compressive strength and abrasion resistance. By its character, this type of steel has high resisting nature against wear and can be used for components which are subjected to severe abrasion, wear or high surface loading.

DESIGN OF EXPERIMENTS

The design of experiments technique is a very powerful tool, which permits to carry out the modeling and analysis of the influence of process variables on the response variables. The response variable is an unknown function of the process variables, which are known as design factors. The purpose of running experiments is to characterize unknown relations and dependencies that exist in the observed design or process, i.e. to find out the influential design variables and the response to variations in the design variable values. A scientific approach to planning the experiment must be employed if an experiment is to be performed most efficiently. The statistical design of experiments refers to the process of planning the experiment so that appropriate data that can be analyzed by statistical methods will be collected, resulting in valid and objective conclusions in a meaningful way. When the problem involves data that are subject to experimental errors, statistical methodology is the only objective approach to analysis. Sometimes, experiments are repeated with a particular set of levels for all the factors to check the statistical validation and repeatability by the replicate data. This is called replication. To get rid of any biasness, allocation of experimental material and the order of experimental runs are randomly selected. This is called randomization. To arrange the experimental material into groups, or blocks, that should be more homogeneous than the entire set of material is called blocking. So, when experiments are carried out these things should be remembered. There are several methodologies for design of experiments. Central composite design method is used in the present thesis.

EXPERIMENTAL SET UP

The experiments have been conducted on the Electrical Discharge Machine model ZNC of Electronica available at large number of input parameters which can be varied in the EDM process, i.e. Discharge voltage, pulse on, pulse off, polarity, peak current, electrode gap and type of flushing, each having its own effect on the output parameters such as tool wear rate, material removal rate, surface finish and hardness of machined surface. Current, Discharge voltage, pulse on and Duty factor are the parameters which were varied on the machine for experimentation. The ranges of these parameters for the experimental work have been selected on the basis of results of previous research work in literature review.

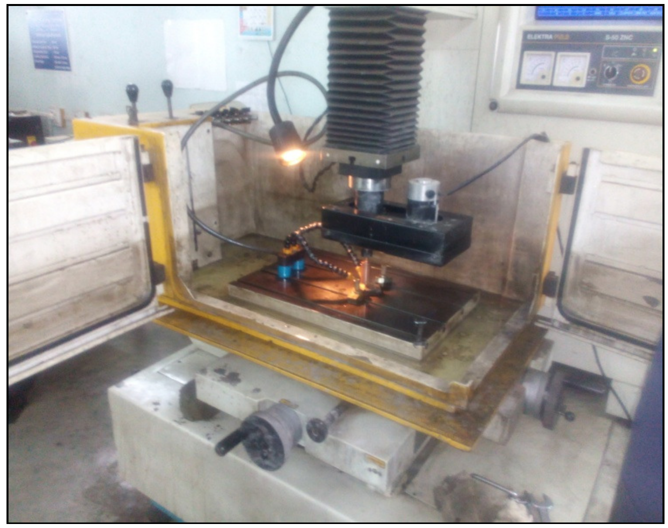

Figure 1 Electrical Discharge Machine **Figure 2 a pictorial view of the experimental set-up for the EDM**

MEASURING AND TEST EQUIPMENT USED

Surface roughness tests were conducted on all the samples produced after each of the 30 trials. Surface roughness was measured using the Surf Test model SJ210 of Mitutoyo, Japan available in the Metrology lab of RIT, Islampur. The equipment uses the stylus method of measurement, has profile resolution of 12 nm and measure roughness up to 100µm. A tracing length of 4.8 mm was used for analysis. Surface roughness of each sample was measured at three different.
Also, MRR was measured using a weighing machine of Contech model CA-503 available in the Metrology lab of RIT, Islampur. The details of important test equipment used in experimental study are given below:

Figure 3 Weighing Machine **Figure 4 Surface Testing Machine**

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MACHINE TOOL

Experiments are carried out using CNC EDM (ZNC50) (Electronica) die sinking machine (shown in fig 1 Table 1 shows the specification of die sinking EDM machine.

Table 1 specification of die sinking EDM machine

Mechanism of Process	**Controlled erosion (melting and evaporation) through a series of electric spark**
Peak Current (Ip)	0-50 (Amp)
Pulse on Time (Ton)	0-3000 (sec)
Gap Voltage (Vg)	0-100 (volt)
Spark gap	0.010 -0.500 mm
Spark frequency	200-500 kHz
Peak voltage across the gap	30-250 V
Shapes	Micro holes, Narrow slots, Blind Cavities
Dielectric Fluid	EDM oil, Kerosene liquid paraffin, Silicon oil, de-ionized water etc.
Specific Power Consumption	2-10 $W/mm^3/min$
Metal Removal Rate (Max.)	5000 mm^3/min
Tool Material	Copper, Brass, Graphite ,Ag-W Alloys, Cu-W Alloys
Limitations	High Specific Energy Consumption, Non-Conducting Material can't be machined.

EDM PROCESS PARAMETERS

1. Polarity
2. Pulse on time
3. Pulse off time
4. Peak current
5. Discharge current
6. Pulse wave form
7. Type of dielectric medium
8. Type of flushing
9. Electrode gap
10. Electrode material

Table 2 Fixed Input Process Parameters

Sr. No.	Working conditions	Description
1	Electrode material	Electrolytic copper
2	Electrode polarity	Negative
3	Specimen material	Alloy steel (EN- 31)
4	Working area ($Inch^2$)	2X 2
5	Dielectric fluid	EDM Oil
6	Fluid pressure (kg/mm^2)	2.0
7	Working time (min)	20/15/10

RESULTS & DISCUSSIONS

Table 3 Output Surface Roughness

Run	Ip	Te	T	V	S.R. in Ra(μ)
1	12	150	0.7	100	10.556
2	12	150	0.11	100	9.184
3	12	150	0.7	60	8.689
4	8	100	0.9	80	7.865
5	12	100	0.9	80	7.539
6	8	150	0.7	80	7.501
7	12	50	0.7	100	7.415
8	12	50	0.11	100	6.574
9	8	100	0.9	100	6.518
10	12	150	0.11	60	6.5
11	8	100	0.9	80	6.454
12	8	100	0.9	80	6.451
13	8	100	0.7	80	6.378
14	12	50	0.11	60	6.339
15	8	100	0.11	100	6.327
16	8	100	0.9	80	6.25
17	4	150	0.7	60	6.206
18	8	100	0.9	80	6.182
19	8	50	0.7	80	6.106

20	4	150	0.11	60	6.075
21	4	150	0.7	100	6.064
22	4	100	0.9	80	6.023
23	8	100	0.9	80	5.907
24	8	100	0.9	60	5.623
25	12	50	0.7	60	5.189
26	4	50	0.11	60	4.709
27	4	50	0.7	60	4.317
28	4	50	0.7	100	4.25
29	4	50	0.11	100	4.031
30	4	150	0.11	100	4.031

CONCLUSIONS

Mathematical models SR were carried out to correlate dominant machining parameters, including the discharge current, pulse on time, duty factor, and open discharge voltage, in the EDM process of alloy steel(EN-31). An experimental plan of a face- centered CCD based on the RSM was employed to carry out the experimental study. The influences of the machining parameters on the performance characteristics in the EDM process of alloy steel (EN-31) were analyzed based on the developed mathematical model to yield the following conclusions especially here we focused on **surface roughness** (S.R.) for this paper:

1. The value of SR first decreases with an increase of pulse on time before 150μs and then increases with further increase in pulse on time. The value of SR increases with an increase of discharge current and open discharge voltage, but, decreases with an increase of duty factor.
2. Surface Roughness value reduces with decreasing Peak Current (Ip)
3. Surface Roughness value reduces with increasing of Gap Voltage (Vg) OR simply Voltage

FUTURE SCOPE

In the present work only these variables i.e. peak current, pulse time, duty factor and open discharge voltage are considered these responses i.e. surface roughness, electrode wear rate, and material removal rate are considered for analysis. In future, the work may be extended for many other variables like gap voltage, Intensity, flushing pressure, dielectric fluid, sparking time, spark gap etc. for other responses like overcut and the responses which are covered in the present work.

Modern electrode material may be tried for minimum electrode wear and maximum material removal rate with a good surface finish.

The process can be optimized for the minimum electrode wear and maximum material removal rate with a good surface finish by using modern techniques.

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