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Optimization of Parameters on EDM Machine on H13 Using Taghuchi & ANOVA Technique

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Abstract: ***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). 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. This new research shares the same objectives of achieving more efficient metal removal rate reduction in tool wear and improved surface quality. This paper reviews the research work carried out from the inception to the development of die-sinking EDM, Water in EDM, dry EDM, and Powder mixed electric Discharge Machining, Within the past decade. & also briefly describing the Current Research technique Trend in EDM, future EDM research direction.***

Keywords: H13, Taguchi, ANOVA, EDM

1. Introduction

Electrical discharge machining is a Thermo-electric non-traditional machining processes. Local melting of the material and content of the workpiece is removed through evaporation. Electric sparks caused by sparks between two electrode surfaces are generated between the two electrodes via an electrode dielectric a short distance from each other and are held at a high potential difference is applied across them. Localized high temperature areas are formed. Workpiece material in the local area melts and evaporates. Most of molten and vaporized material from the inter-electrode spacing of debris particles carried by the dielectric flow.

To prevent excessive heating, electricity is supplied as short pulses. Spark is where the gap between the tool and the workpiece surface is the smallest. A spark material, the difference increases to a different point on the surface of the workpiece shifts the position of the spark is removed later. In this way many sparks workpiece- equipment at various locations on the entire surface of the gap are the same. Sparks caused by the removal of material, after some time interval of an equal distance across the gap between the tool and the workpiece is formed. Device is held steady; the machining will stop at this level. But if the device in the direction of the workpiece is continuously fed more material is removed and the process is repeated. Has achieved the required depth of cut until the tool is fed. Finally, the device size replica of a cavity is formed on the same workpiece.

The work tool and workpiece as the electrode in electrical circuits. Pulsed power from a separate power supply unit is supplied to the electrodes. workpiece feed speed appropriate to the device generally shown in Figure 1 between tool and workpiece during machining to maintain a constant gap distance is provided.

Figure 1: Electronic EDM spark erosion 500x300

2. Principles of EDM

Electrical Discharge Machining (EDM) is a controlled removal of metal through the electric spark erosion is used to extract the metal. In the process, the cutting tool to cut an electrical spark (Erode) finished work piece part production to the desired size as is used. The process of removing metal electrode to the work piece through a pulsing (on / off) of the high frequency current is performed by applying electrical charge. This removes the metal work piece at a controlled rate (impaired) is very small.

Application of EDM

- The EDM process is most widely used by the mould-making tool and die industries, but is becoming a common method of making prototype and production parts, especially in the aerospace, automobile and electronics industries in which production quantities are relatively low.
- Extremely hard materials can be easily machined that are difficult to machine like alloys, tool Steels, tungsten carbides etc.
- Sharp edges and corners that cannot be machined can be machined effectively by other machining processes.
- Electric Discharge Machining has also made its presence felt in the new fields such as sports, Medical and surgical, instruments, optical, including automotive R&D areas.

Advantages of EDM

- An electrically conductive material that can be cut using the EDM process.
- Heat treatment of hard work pieces can be machined, eliminating distortion.
- Dies and molds campus classes, the right can be produced faster, and at lower cost.
- The EDM process is burr-free.
- Such as webs or thin delicate wings easily share classes can be machined without deforming.

Limitations of EDM

- The need for electrical conductivity - the discharge may be able to create; the work piece has to be electrically conductive. Insulators, plastic, glass, ceramics and the like, cannot be machined by EDM.
- The difference predictability - a gap dimension always readily predictable, especially with complex work piece geometry are not. In these cases, flushing conditions and state pollution differ from one specified.

3. Literature Review

J. Jeykrishnan et al. (2016) investigates in optimizing the process variables of EDM by employing a traditional technique. The parameters chosen for optimization are pulse on time, pulse off time followed by the current and L_9 Orthogonal Array (OA) has been selected to examine the impact of the process variables on the performance i.e. on the material removal rate. The experimental trials have been done on AISI D2 die steel with positive polarity and brass has been chosen as an electrode material.

Bhoj Raj Chaudhary et al. (2016) presents an overview of parameters like current, pulse on time, electrode and duty cycle for the material EN 32 steel tool. Here parameters are optimized according to Taguchi Method and L16 orthogonal array is used for 4 levels of optimization.

Vishal J Nadpara et al. (2016) experimented on AISI D3 tool steel using graphite electrode of 10 mm diameter. The process parameters are taken on the basis of Taguchi method. The objective of the paper is to optimize the process parameters of machining in high, medium and low wear factors through duty cycle.

Modi et al. (2015) studied EDM process parameters so that the whole process is affected by the electrical and non-electrical. The project work rotating equipment metal removal rate (MRR) to improve and to monitor its impact on surface finish is used. Taguchi method of experiments and response surface methodology for analysis and optimization of a design is used.

Pradhan et al. (2014) stated that Electrical discharge machining is typically performed based on material removal rate (MRR), tool wear rate (TWR), relative wear ratio (RWR) and surface roughness (SR) is assessed on. EDM machining process performance measures that affect important parameters of the discharge current, pulse time, pulse off time, arc gap, and are duty cycle. A considerable amount of work MRR, TWR, RWR based on EDM performance measurement, and different materials have been reported by researchers at the SR.

Singh et al. (2013) studied the impact on operating parameters such as pulse-time work piece and cryogenic and non-cryogenic DM electrode using steel such as metal removal rate (MRR) and tool wear ratio (TWR) as a response to copper content and pulse time. Cryogenic treatment is increasing material removal rates and tool wear is used to reduce the rate. It was found that the tool wear rate increase with the pulse treatment cryogenic and non-cryogenic copper electrode, both electrodes is decreased. Tool wear rate increases with increasing pulse off time. With the increase in time for the 100 µs pulse of 50 µs and 20 µs to 15 µs pulse of time with increasing material removal rate increased material removal rate has decreased.

4. Experimental Set Up

The EDM experiments were conducted in Sparkonix machine using copper as the tool electrode. The input parameters were Pulse Current (A), Pulse–on–time T_{on} (µs), and Gap Voltage (V). The output measures being the surface roughness of the machined surface of work material (Ra), Material Removal Rate (MRR). Values of the controllable factors were chosen based on the literature review. Four controllable factors were used in the experiments and have been split into three different levels. Moreover, this work adopted L16 orthogonal array based on Taguchi method to conduct a series of experiments to optimize the EDM parameters. Experimental data were evaluated statistically by analysis of variance (ANOVA) and all other machine parameters were kept constant during the time of experiment.

5. Assumptions of Experimentations

1) During the complete process input power supply is constant.
2) The travel of vertical ram of the machine is straight.
3) The fluctuated input current supply is neglected.
4) Run out of spindle is zero.
5) Effects of variation of environmental effects are not considered.
6) Setting of work piece and electrode is same for all experiments.
7) Same dielectric fluid is used for all experiment.
8) Gap between tool and work piece during all the experiment is constant.

Table 1: Shows the work piece detail

Work piece material	H13
Length of work piece	20mm
Diameter of work piece	28 mm
EDM used	Sparkonix MOS 35 A
Tool Material	Copper
Vice used	70x70x30
Depth of throat	250
Environment	Wet
Dielectric Fluid	Kerosene oil

6. Material Used

H13 Tool Steel is a versatile chromium-molybdenum hot work steel that is widely used in hot work and cold work tooling applications. The hot hardness (hot strength) of H13 resists thermal fatigue cracking which occurs as a result of cyclic heating and cooling cycles in hot work tooling applications. Because of its excellent combination of high toughness and resistance to thermal fatigue cracking (also known as heat checking) H13 is used for more hot work tooling applications than any other tool steel.

Table 2: Chemical composition of E 24 steel (wt. %)

Element	C	Mn	P	S	Si	Ni	Cr
Weight %	0.38	1.45	0.0012	0.002	0.37	0.90	1.79

7. Levels of Input Factors

Variable input parameters

Based on the literature review and machine control levels of input factors are finalized. These levels of input parameters and General Linear model for Material Removal rate and Surface Roughness

Table 3: Levels of input control factors with units

Factors	EDM Machining Parameters	Levels				Observed Values
		L1	L2	L3	L4	
A	Pulse -on time (µs)	15	30	50	75	1) Material Removal Rate (mm^3/min) 2) Surface Roughness (R_a)
B	Gap Voltage (volts)	35	40	45	50	
C	Pulse Current (Ampere)	5	7	9	11	

8. Results and Discussion

Analysis of Material Removal Rate

Experiments were conducted using L16 Orthogonal Array shown in Table5.1 to find the effect of process parameters on the MRR. The experiments were done on H13 Steel. The rate of cutting speed for each work piece and tool materials were collected in same experimental conditions. After performing experiment MRR value is recorded in each experiment shown in Table 4

Table4: L16 Orthogonal Array with Performance

Exp No.	Ton (µs)	Gap Voltage (v)	Pulse current (A)	MRR mm^3/min
1	15	35	5	9.52
2	15	40	7	7.25
3	15	45	9	6.04
4	15	50	11	7.86
5	30	35	7	9.88
6	30	40	5	9.74
7	30	45	11	8.59
8	30	50	9	9.39
9	50	35	9	8.16
10	50	40	11	7.71
11	50	45	5	8.41
12	50	50	7	9.01
13	75	35	11	9.32
14	75	40	9	7.25
15	75	45	7	8.26
16	75	50	5	9.51

Table 5: Analysis of variance (ANOVA) for S/N Ratio w.r.t MRR

Source	DF	Seq SS	Adj SS	F	P
T_{on}	3	6.1665	2.05551	20.59	0.001
Gap voltage	3	5.7293	1.90978	19.13	0.002
Pulse Current	3	5.1315	1.71049	17.14	0.002
Error	6	0.5988	0.09981		
Total	15	17.6262			

The table 5 includes ranks based on delta statistics, which compares the relative magnitude of effects. The delta statistic is the highest average minus the lowest average for each factor. Minitab assigns ranks based on delta values in descending order; the highest delta value has rank. 1 and rank 2 is assigned to the second highest, and so on. The ranks indicate the relative importance of each factor to the response.

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Table 6: Response Table for Signal to Noise Ratio Larger is better

Level	Ton (µs)	Gap Voltage	Pulse Current
1	7.667	9.220	9.295
2	9.400	7.988	8.600
3	8.322	7.825	7.710
4	8.585	8.942	8.370
Delta	1.733	1.395	1.585
Rank	1	3	2

Analysis of variance (ANOVA) is performed and signal-to-noise (S/N) ratio will be determined to know the level of importance of the machining parameters. To obtain the optimal machining performance the higher the better quality characteristics for MRR.As can be seen from Table (above), the MRR is most significantly influenced by the T_{on} followed by the Gap Voltage. The respective values of these parameters are 1.733 and 1.585. After finding all the observation as given in Table 5.2 & 5.3, S/N ratio are calculated and graph for analysis is drawn by using MINITAB 17 software. The S/N ratio for MRR is calculated on MINITAB 17 Software using Taguchi Method.

The S/N response graph for Material Removal rate is shown in Fig 2. The greater average S/N ratio corresponds to the max MRR. From the S/N response graph Fig5.1, it is concluded that the optimum parametric combination is T_{on} (30), Pulse Current (5A), and Gap Voltage (35V). In other words, it is this combination of parameters that gives the max MRR for the machined material.

Figure 3 shows the interaction between the pulse current, pulse on and gap voltage. Mean data interaction for material removal rate (MRR). Fig 5.3 shows surface roughness measuring instrument.

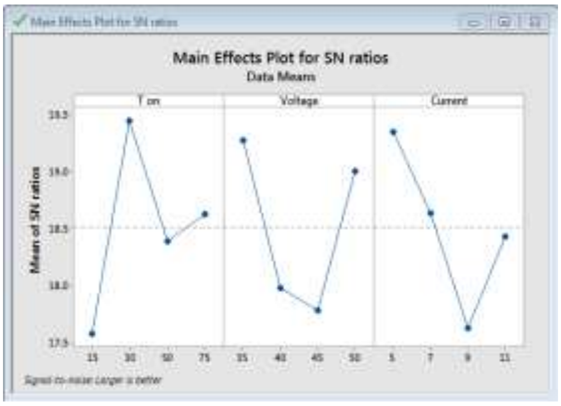

Figure 2: S/N Ratio for MRR

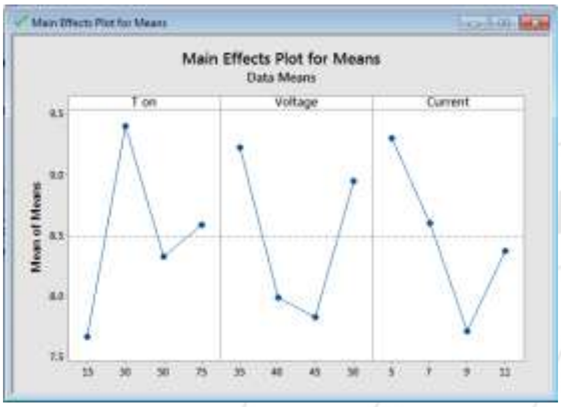

Figure 3: Means for MRR

Analysis of Surface Roughness

Experiments were conducted using L16 Orthogonal Array to find the effect of process parameters on the SR. The experiments were done on H13 Steel. The rate of cutting speed for each work piece and tool materials were collected in same experimental conditions. After performing experiment Ra value is recorded in each experiment shown in Table 7.

Table 7: TheL16 Orthogonal Array with Performance

Exp No.	Ton (µs)	Gap Voltage (v)	Pulse current (A)	R_a
1	15	35	5	6.18
2	15	40	7	5.24
3	15	45	9	4.35
4	15	50	11	5.35
5	30	35	7	4.20
6	30	40	5	5.38
7	30	45	11	4.25
8	30	50	9	3.32
9	50	35	9	5.05
10	50	40	11	5.23
11	50	45	5	4.53
12	50	50	7	4.48
13	75	35	11	6.23
14	75	40	9	5.25
15	75	45	7	4.28
16	75	50	5	5.24

Table 8: Analysis of variance (ANOVA) for S/N Ratio w.r.t TWR

Source	DF	Seq SS	Adj SS	F	P
T_{on}	3	2.5907	0.86355	9.93	0.010
Gap voltage	3	3.1869	1.06228	12.22	0.006
Pulse Current	3	2.4338	0.81125	9.33	0.011
Error	6	0.5215	0.08692		
Total	15	8.7328			

The Table 9 includes ranks based on delta statistics, which compares the relative magnitude of effects. The delta statistic is the highest average minus the lowest average for each factor. Minitab assigns ranks based on delta values in descending order; the highest delta value has rank. 1 and rank 2 is assigned to the second highest, and so on. The ranks indicate the relative importance of each factor to the response.

Table 9: Response Table for Signal to Noise Ratio Smaller is better

Level	Ton (µs)	Gap Voltage	Pulse Current
1	5.280	5.5415	5.332
2	4.287	5.275	4.550
3	4.823	4.353	4.492
4	5.250	4.598	5.265
Delta	0.992	1.063	0.840
Rank	2	1	3

According to the Minitab software the graphs show that best values of parameters are T_{on} (30), Pulse Current (9A) ampere and gap voltage (45V) but, these values do not lie in orthogonal array L16 table.

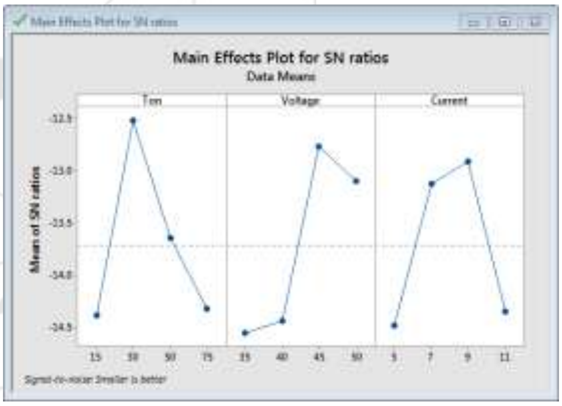

Figure 4: Shows the S/N ratio for Tool Wear Rate

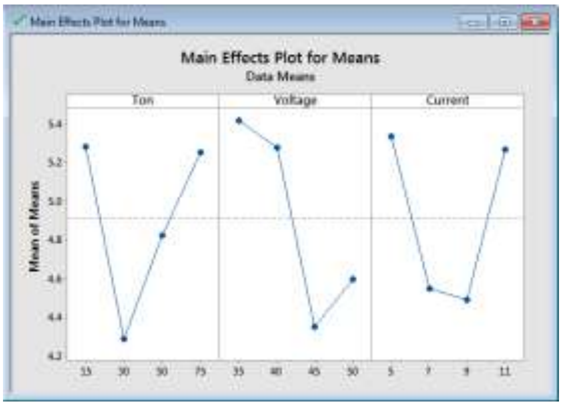

Figure 5: Shows that means for Tool Wear Rate

9. Conclusion

1) Gap Voltage has a greater influence on the surface Roughness followed by T_{on} Time. Pulse Current had the least influence on Roughness.
2) T_{on} Time is the most significant parameter for Material Removal Rate, followed by Pulse Current and Gap Voltage respectively.
3) The optimum parameters for Surface Roughness are Pulse on Time (30µs), Pulse Current (9A) and Gap Voltage (45V).
4) The ideal parameters for material removal rate are Pulse on Time (30µs), Pulse Current (5A) and Gap Voltage (35V) that results in MMR.

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